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DOE/EV-0005/29
ORNL-5734

Radiological Survey of the Former Kellex Research Facility, Jersey City, New Jersey

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OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DOE/EV-0005/29
ORNL-5734
Dist. Category UC-70

Contract No. W-7405-eng-26

Health and Safety Research Division

RADIOLOGICAL SURVEY OF THE FORMER KELLEX RESEARCH FACILITY, JERSEY CITY, NEW JERSEY

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Worked performed as part of the
Remedial Action Survey and
Certification Activities

Date Published: February 1982

OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

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ACKNOWLEDGEMENTS

Research for this project was sponsored by the Division of Environmental and Safety Engineering (then Environmental Control Technology), U. S. Department of Energy, under contract W-7405-eng-26 with Union Carbide Corporation. The authors wish to acknowledge the continued support and encouragement of William E. Mott, Director, Environmental and Safety Engineering Division, and members of his staff. Appreciation is extended to J. F. Emory and Joe Northcutt, ORNL Analytical Chemistry Divsion for their careful analysis of environmental samples for uranium, to P. T. Perdue for his gamma-ray spectral analysis of soil samples, to B. S. Ellis for her management of samples analysis records, and to Roxanne Rabe and Wilma Minor for their manuscript typing. The authors wish to acknowledge the valued radiation survey work of their deceased co-author, William M. Johnson. This report is dedicated to him.

RADIOLOGICAL SURVEY OF THE FORMER KELLEX RESEARCH FACILITY, JERSEY CITY, NEW JERSEY

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ABSTRACT

A radiological survey has been conducted at the site of the former Kellex Corporation Research Facility in Jersey City, New Jersey. Kellex played a major role in the Manhattan Project, particularly in the area of engineering research in gaseous diffusion for uranium enrichment. As a result of those operations and subsequent work with radioactive materials, this site was selected for a radiological survey by the Department of Energy (DOE) [then Energy Research and Development Administration (ERDA)] in its program aimed at reviewing and documenting the radiological status of properties associated with early source material contracts. The survey included measurement of external gamma radiation, beta-gamma surface dose rates, alpha and beta surface contamination, concentrations of selected radionuclides in surface and subsurface soil and water on the site, and background radiation in the northern part of New Jersey. The results of the radiological survey indicate radionuclide concentrations in the soil and water on the former Kellex property are within background levels, with the exception of nine isolated and well-defined areas on the site of the former Kellex Laboratory.

*Deceased.

INTRODUCTION

At the request of the Department of Energy (DOE) [then Energy Research and Development Administration (ERDA)], a radiological survey was conducted at the former M. W. Kellogg Company in Jersey City, New Jersey.* The site, located at the intersection of New Jersey Route 440 and Kellogg Street, was an industrial park which included the Kellex Corporation Research Facility. Figures 1-5 are aerial photographs of the Kellex site between 1940 and 1966. The photographs reflect the changing on-site conditions with time. A diagram of the Kellex site indicating the location and orientation of the on-site buildings at the time the facility was operational (1943-1952) is shown in Fig. 6. All of these buildings have been removed since that time.

Kellex was formed by Kellogg in 1943 to carry out engineering research in gaseous diffusion for uranium enrichment as a part of the Manhattan Project. The main research activities of Kellex involved component testing with uranium hexafluoride.

According to sparse records of early (1951-1953) radiological surveys conducted by the AEC's New York Operations Office, it was believed that all of Kellex's operations were initially conducted in a single building on the site. This building was designated Building 11 and contained several laboratories, offices, weighing facilities, toilets, change rooms, and a shielded counting room. The radioactive materials handled in this building included material from a "purex" uranium recovery process, natural uranium, and some pitchblende. There was no information regarding any other radioactive material which might have been handled in this building, nor was there any information regarding the relative quantities of such materials from the purex process, uranium, or pitchblende.

In early 1943, uranium hexafluoride research was transferred from Building 11 to Building A on the western edge of the site[1] (Fig. 6).

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*The survey was carried out in two phases. Initial work was done in March 1977. Additional survey work was conducted in the summer of 1979.

ORNL-Photo 5190-79

Fig. 1. Aerial photograph of the Kellex site and surrounding area in April, 1940.

ORNL-Photo 4329-79

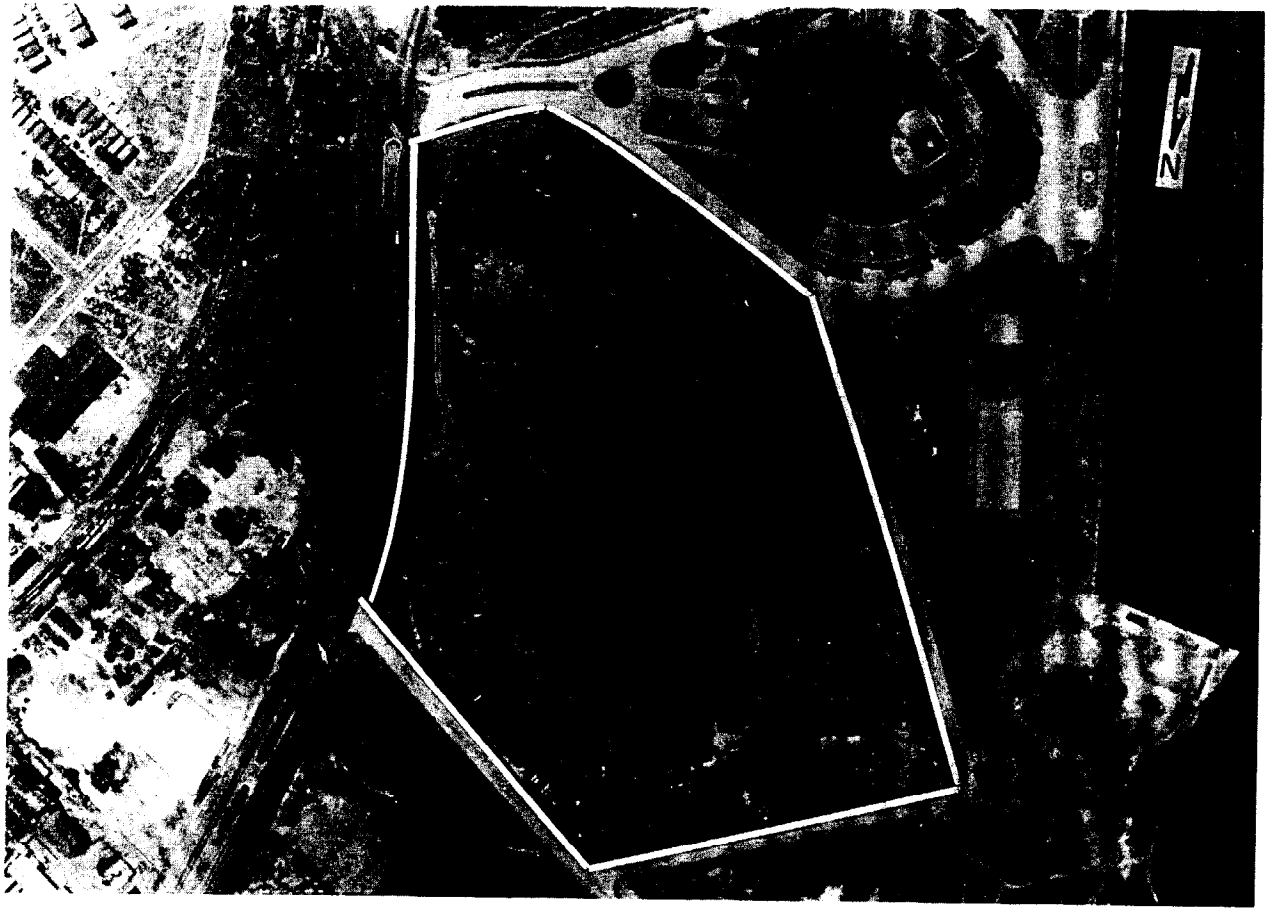

Fig. 2. Aerial photograph of the Kellex site and surrounding area in January, 1944.

ORNL-Photo 5191-79

Fig. 3. Aerial photograph of the Kellex site and surrounding area in April, 1951.

ORNL-Photo 5192-79

Fig. 4. Aerial photograph of the Kellex site and surrounding area in April, 1961.

ORNL-Photo 5193-79

Fig. 5. Aerial photograph of the Kellex site and surrounding area in June, 1966.

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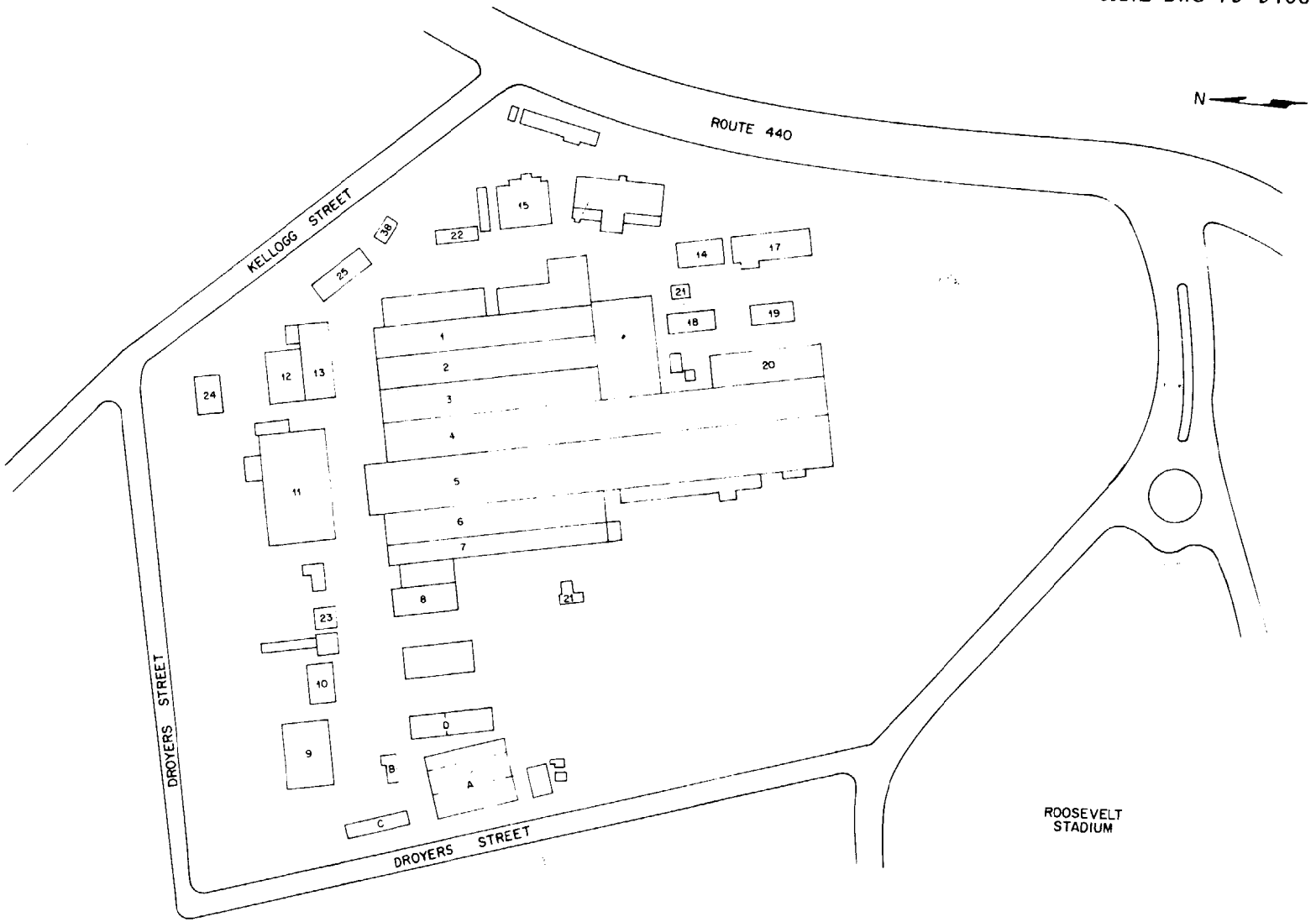

Fig. 6. Location and orientation of the buildings at the Kellex site during operations (1943 to 1952).

In 1945, all gaseous diffusion equipment was removed and relocated to the Oak Ridge Gaseous Diffusion Plant (K-25) in Oak Ridge, Tennessee.

On June 25, 1953, a *Contamination Status Report* was published by the Vitro Corporation of America and detailed the findings of a "final radiation and contamination survey" of the Jersey City Laboratory (Appendix I). In this report, it was indicated that most external gamma radiation readings were less than 100 μR/h*, and no transferable alpha or beta-gamma contamination was observed in any of the accessible areas. Some elevated gamma-ray readings were noted in a duct used for exhausting hoods in two of the laboratories in Building 11. One reading equivalent to 600 μR/h was observed on a wall in the chemical storage area. Since 1953, Building 11 has been demolished. Its location was estimated from a sketch of the property which was made in the 1960s and is shown by a dotted outline in Figs. 7 and 8. In the above report, there was no mention of the gaseous diffusion research which was conducted in Building A (Fig. 6) nine years earlier, and no measurements were taken in that building.

Ownership and use of the property have also changed since 1953. The site of the laboratory is currently owned by Pierpont Associates, Incorporated, and managed by Harborside Management Company. Approximately 17 ha (43 acres) of the original property have been sold. A portion of the Pierpont Associates property is occupied by a Pathmark supermarket and its parking lot. Approximately 10 ha (25 acres) remain under Pierpont ownership, including the laboratory site where radioactive materials were handled. A large portion of this property is currently occupied by Stadium Plaza, a new shopping center with associated parking lots (Fig. 9).

A preliminary survey of the Kellex site was made by a DOE representative and an Oak Ridge National Laboratory (ORNL) health physicist on October 21, 1976. This cursory survey of the property revealed average external gamma-ray readings of 5 to 6 μR/h. For the northeastern part of the United States, this is approximately equivalent to natural background radiation levels. However, it was decided that a

*Conversion for SI units are located in Appendix II.

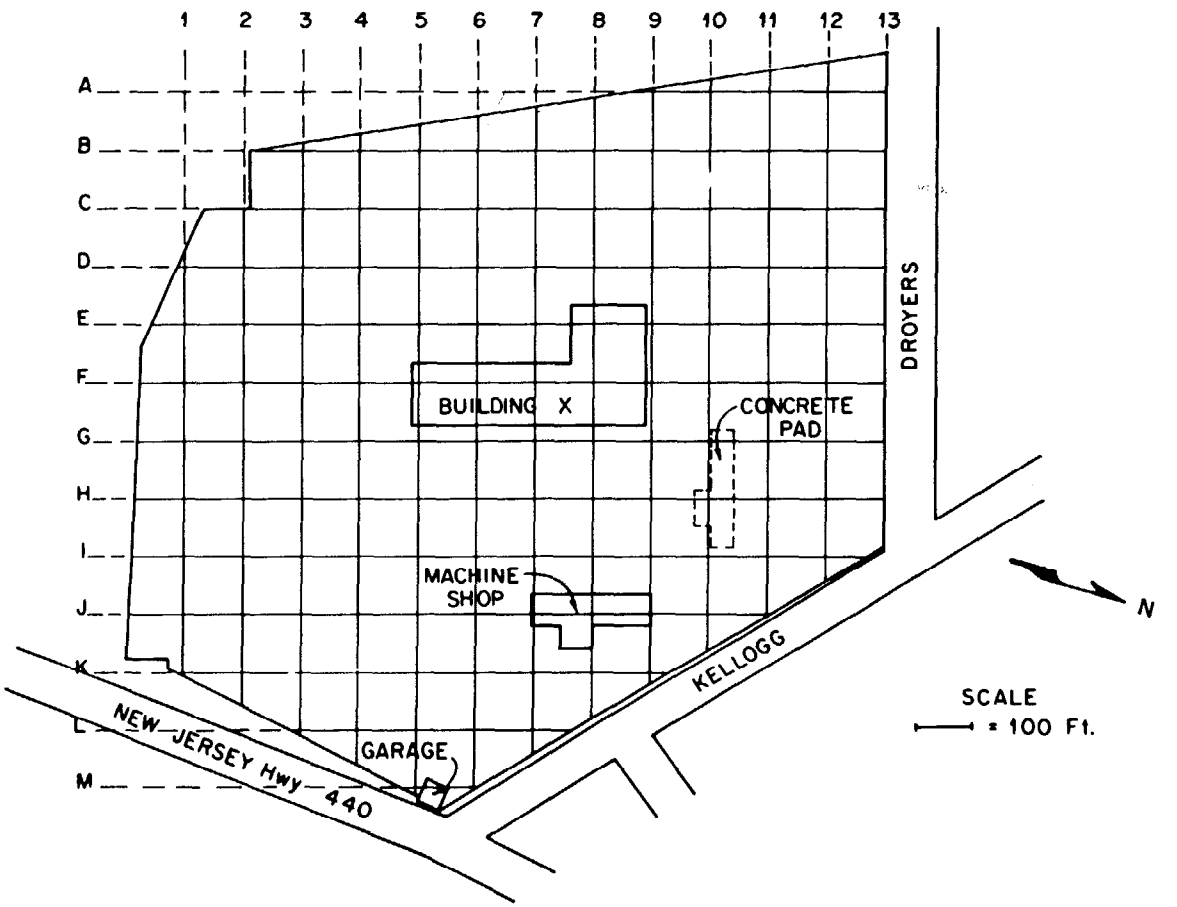

Fig. 7. Extent of former Kellex site as surveyed in 1977 radiological assessment. (Building X was a portion of Building 11; the machine shop was a portion of Building 1.)

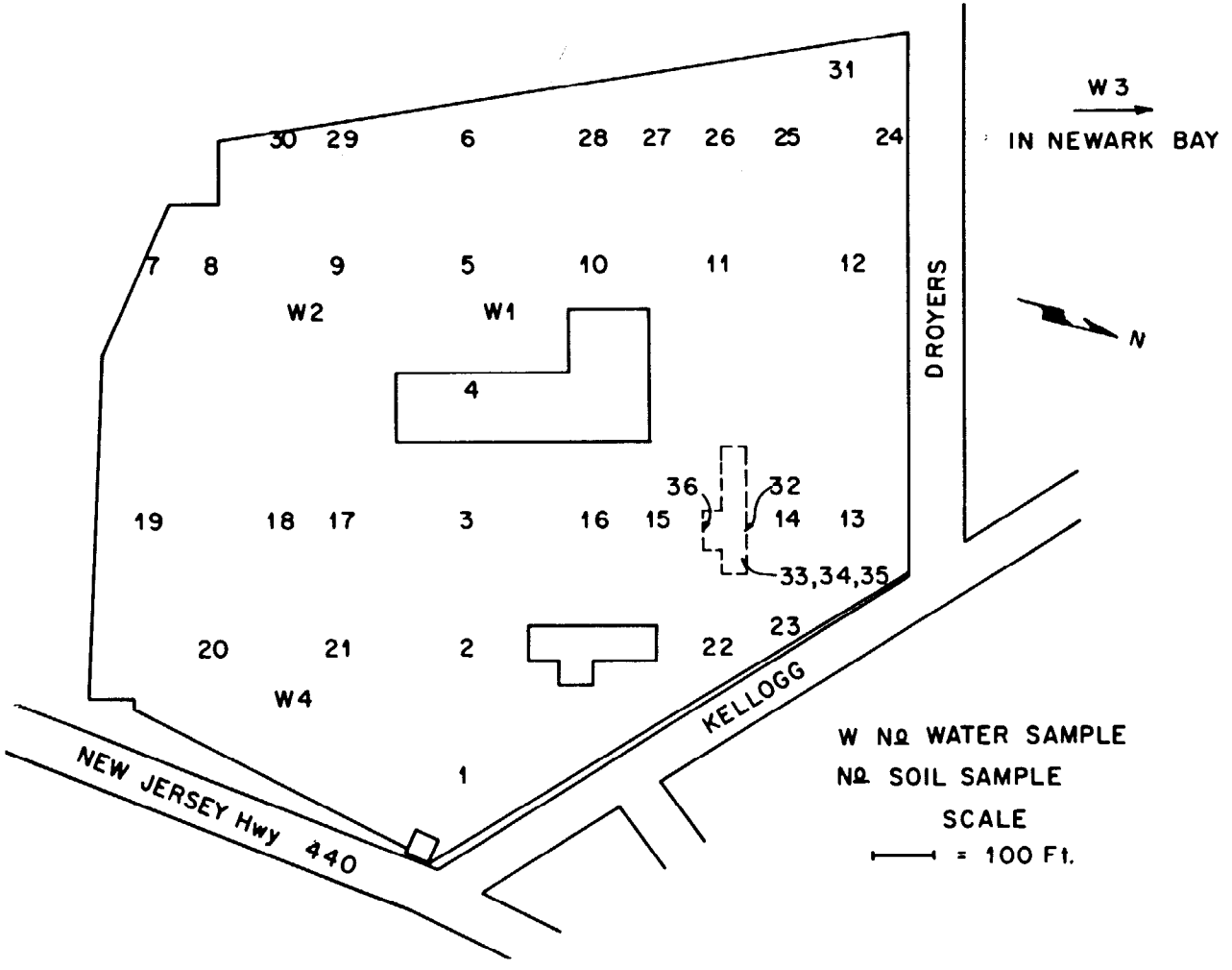

Fig. 8. Site plan and location of surface soil and water samples taken at the former Kellex site.

formal survey should be conducted due to the size of the property and uncertainty as to the exact location and extent of Kellex operations.

In addition to the concrete pad of the old laboratory, three buildings were still standing on the property at the time of the October, 1976, visit but were later demolished. One of these was most likely the remains of the original Buildings 6, 7, and 8 (Fig. 6) which were contiguous. This structure was vacant and will be referred to as Building X in Fig. 7. Another building was probably the remains of the structure immediately east of Building 1 in Fig. 6. This building was used at the time of the 1977 survey as a machine shop and will be so identified in this report. The third and final remaining structure during the 1977 survey was a small building fronting Route 440 which was used as the Plymouth-Chrysler garage (Fig. 7). This building will be referred to as the "garage" in this report.

SURVEY PLAN

A series of surveys were undertaken to characterize the existing radiological status of the Kellex site. They were conducted by members of the Health and Safety Research Division of ORNL. The first formal survey, performed on March 28-30, 1977, included the following measurements:

1. measurement of external gamma radiation levels at 1 m above the surface at grid points of an approximate 30-m grid over the entire property as shown in Fig. 7;
2. measurement of beta-gamma dose rates at 1 cm above the surface using the same grid;
3. measurement of the concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in surface soil samples located as shown in Fig. 8;
4. measurement of the concentrations of ^{210}Pb, ^{226}Ra, ^{230}Th, and ^{238}U in surface (including drainage) water samples located as shown in Fig. 9;

ORNL-DWG 79-20265

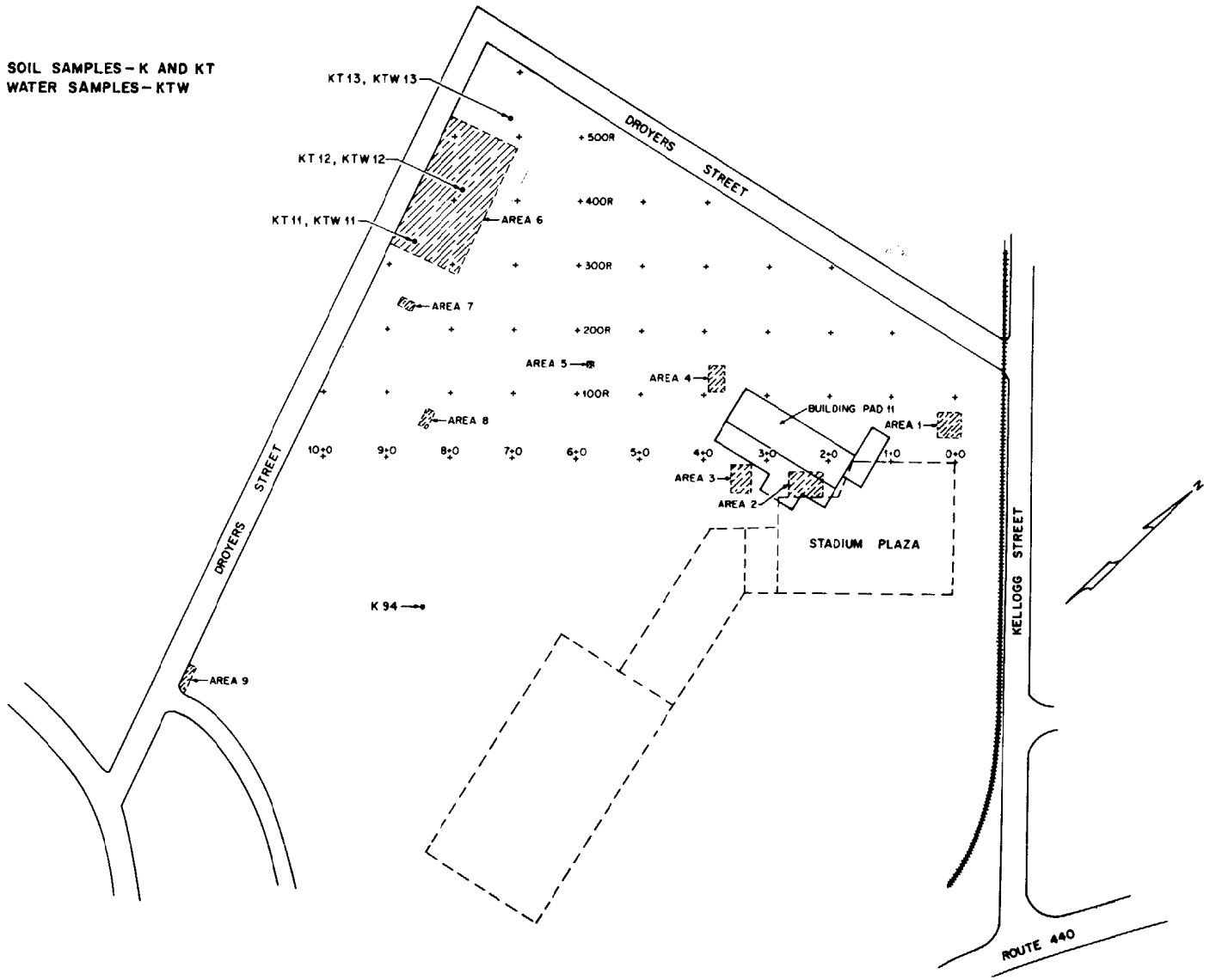

Fig. 9. Site plan and location of grid system and selected sample areas on the Kellex site.

5. measurement of fixed alpha contamination levels, beta-gamma dose rates at 1 cm, and gamma radiation levels at 1 m above the surfaces on an approximate 3-m grid on the concrete pad at Building 11 as shown in Fig. 10;
6. measurement of transferable alpha and beta contamination on the concrete pad of former Building 11;
7. measurement of the concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in scale samples taken from floor drains in the concrete pad of Building 11;
8. measurement of external gamma radiation levels at 1 m, beta-gamma dose rates at 1 cm above the surfaces, and alpha contamination by direct reading in the three buildings remaining on the site: the garage, the machine shop, and the large empty building designated as Building X in Fig. 7; and
9. background measurement of external gamma radiation levels and concentrations of ^{226}Ra, ^{232}Th, and ^{238}U in surface soil and ^{210}Pb, ^{226}Ra, ^{230}Th, and ^{238}U in surface water samples at points near, but assumed not influenced by, the former Kellex Corporation operations.

Several additional surveys were performed at the Kellex site during 1979 (March 27, May 10-11, June 2, July 21, August 1-4, and August 30-31).

The additional surveys in 1979 included the following:

1. measurement of external gamma exposure rates at the ground surface in walk-over traverses less than 3 m apart over the property shown in Fig. 11;
2. measurement of concentrations of ^{238}U, ^{226}Ra, and ^{232}Th in soil at variable depths in Areas 1-9 identified in Fig. 9 ;
3. measurement of concentrations of ^{226}Ra, ^{238}U, ^{232}Th, ^{230}Th, and ^{210}Pb in three groundwater samples at locations shown in Fig. 9; and

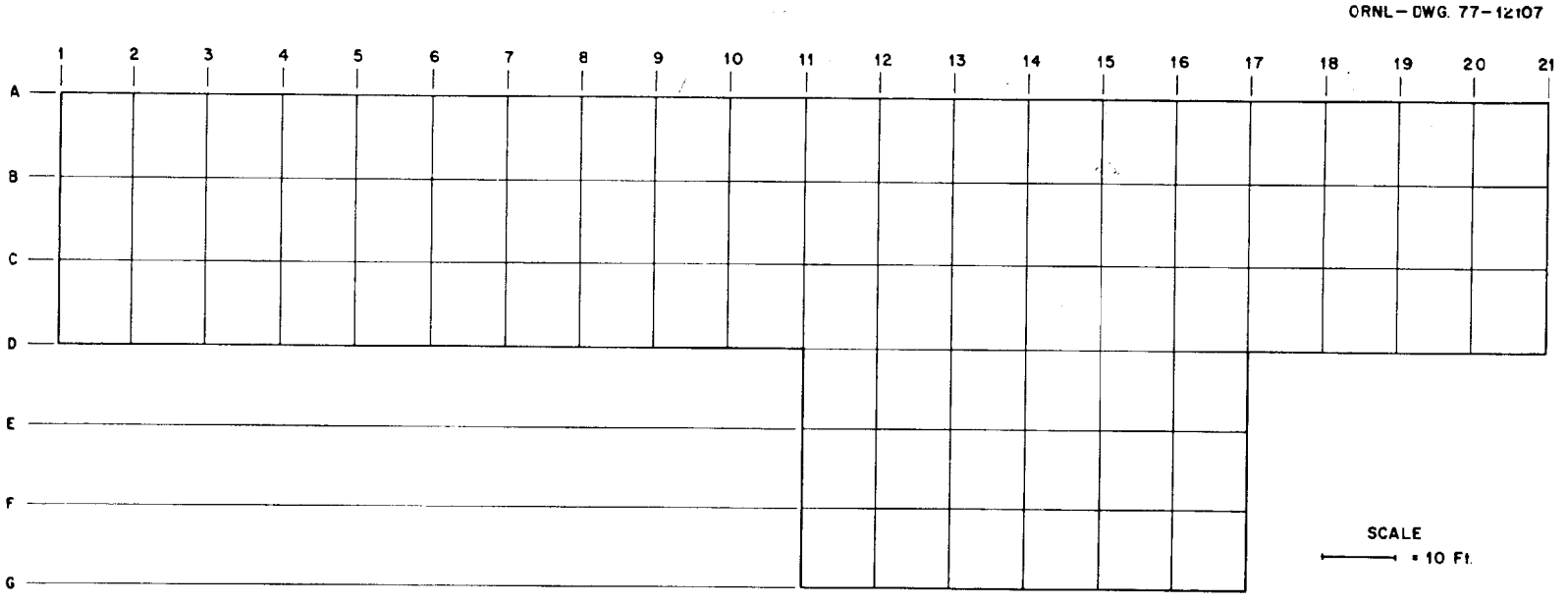

Fig. 10. Grid used for external gamma radiation measurements on the concrete pad of former Building 11.

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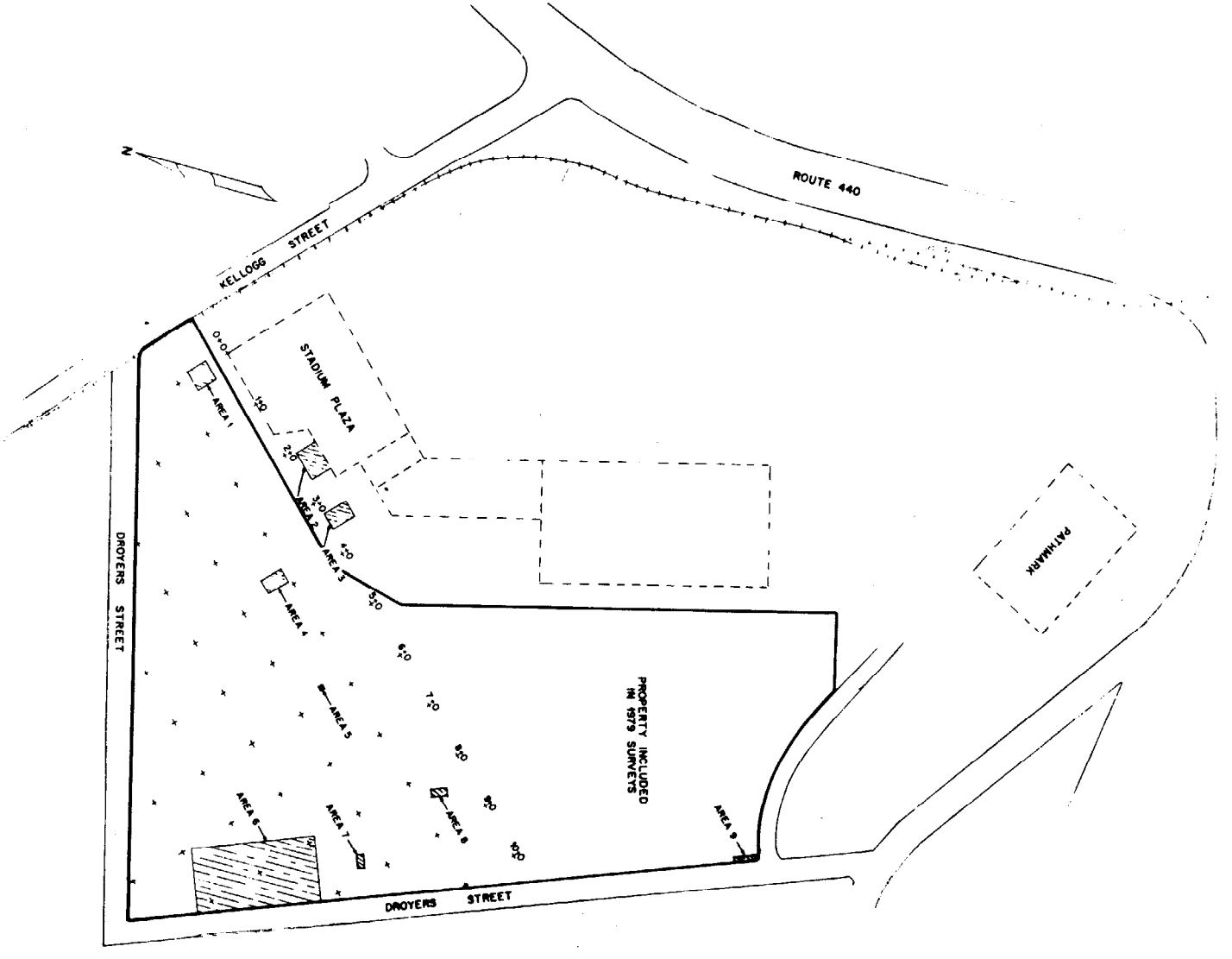

Fig. 11. Property on the Kellex site included in the 1979 surveys with identification of the nine areas where elevated external gamma exposure rates were elevated.

4. drilling and gamma logging of 27 holes on the Kellex site as a means to estimate the ^{226}Ra concentration in soil as a function of depth at locations identified in Fig. 12.

RADIOLOGICAL SURVEY TECHNIQUES

This section describes the instrumentation and techniques used to carry out the radiological surveys of the Kellex site.

External Gamma Radiation

During March, 1977, external gamma radiation level measurements were made at 1 m above the surface using NaI(Tl) scintillation survey meters which are described in Appendix III. Also, external gamma radiation levels were measured inside the machine shop, the garage, and Building X using the same type of instrument.

During the 1979 surveys, external gamma exposure rates were measured at the ground surface in that area indicated in Fig. 11. The gamma-ray scan was made in 3-m-interval traverses.

Scintillation survey meter measurements are indicative of the instantaneous exposure rates at the point of measurement. Because the response of these meters is highly energy dependent, the meter reading was normalized in the field to the exposure rate given by a Geiger-Mueller (G-M) counter[2] equipped with a filter of tin and lead to provide an instrument response nearly independent of photon energy.

Beta-Gamma Dose Rates

In March, 1977, beta-gamma dose rates of 1 cm above the surface were measured at most of the grid locations where external gamma radiation levels were measured. In the 1979 surveys, beta-gamma dose rates were measured only at those locations where low-level radioactive contamination existed. All measurements were made with G-M survey meters, which are described in Appendix III. These meters were

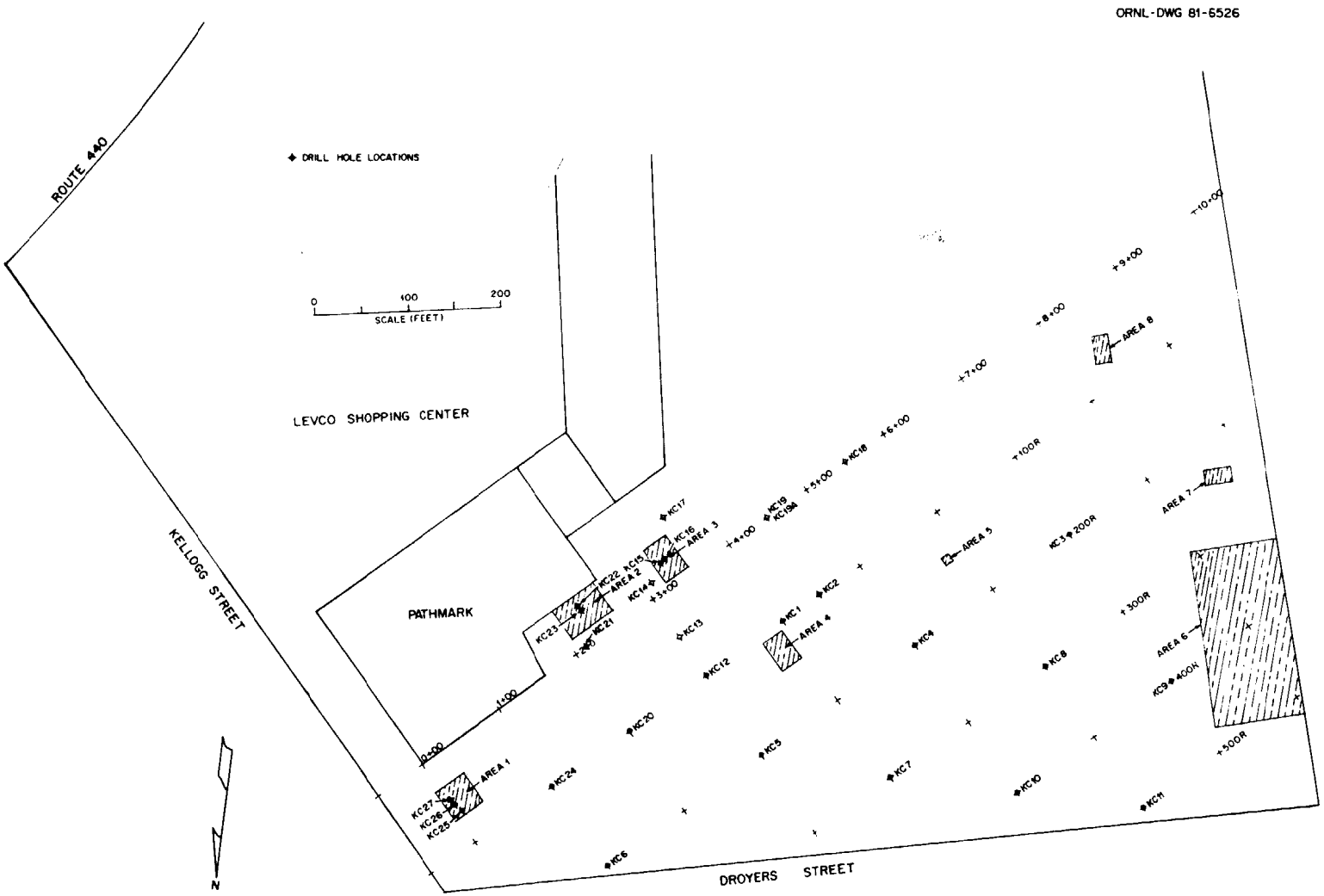

Fig. 12. Location of auger holes on the former Kellex site.

field calibrated by comparison with a Victoreen Model 440 ionization chamber to obtain beta-gamma dose rates.

Alpha and Beta Contamination

Alpha contamination levels were measured during the March, 1977, survey on the concrete pad of Building 11 and in the three buildings left standing: the garage, machine shop, and Building X. Direct readings of alpha contamination levels were made with ZnS(Ag) scintillation survey meters, which are described in Appendix III. Standard smears* were taken on an approximate 3-m grid on the concrete pad of Building 11 and counted using the smear counters described in Appendix III in order to assess the transferable alpha and beta contamination levels. No alpha or beta contamination measurements were made in the 1979 surveys since only open land was surveyed.

Soil Sampling and Analysis

Surface soil samples were taken at locations throughout the property and in drains of former Building 11 as shown in Fig. 8 during the March, 1977, survey. During the 1979 surveys, soil samples were primarily taken at those locations where elevated levels of external gamma exposure rates were observed.

The samples were packaged in plastic bags and returned to ORNL where they were dried for 24 h at 110°C and then pulverized to a particle size no greater than 500 μm in diameter. Next, aliquots from each sample were transferred to plastic bottles, weighed, and stored for approximately one month to allow the ^{226}Ra daughter products to attain secular equilibrium. The samples were counted using a Ge(Li) detector, and the spectra obtained were analyzed by computer techniques. A description of the Ge(Li) detector and soil counting techniques is given in Appendix IV. The concentrations of ^{226}Ra and ^{232}Th

*A standard smear consists of wiping 100 cm^2 of a surface with filter paper or soft absorbent paper and counting this medium with appropriate alpha and beta detectors.

were determined for these samples. A neutron absorption technique was used to determine the concentration of ^{235}U in these samples.

Subsurface Soil Sampling

During the 1979 surveys, 27 holes were drilled in soil from the ground surface to depths between 1.5 and 3 m (5 and 10 ft) with a motorized rig using a 20-cm-diam auger. A plastic pipe (10-cm inside diameter) was placed in each hole, and a NaI(Tl) scintillation probe was lowered inside the pipe. The probe was encased in a lead shield with a horizontal row of narrow collimating slits on the side. This arrangement allowed measurements of gamma radiation intensities resulting from gamma-ray activity within small sections of the hole depth. Measurements were usually made at 31-cm (1-ft) intervals. This "logging" of the auger holes was performed in order to define the profile of radioactivity underground and to estimate the ^{226}Ra concentration as a function of depth.

The NaI(Tl) probe readings are displayed as counts per minute (cpm). It was empirically determined that a conversion factor of 2.0×10^{-3} pCi/g·cpm will yield an approximate estimate (±50%) of ^{226}Ra concentration in soil at the depth the reading was made.

Six soil samples at two drilling locations were obtained for analyses at ORNL.

Water Sampling and Analysis

Surface water samples were taken at the locations shown in Fig. 8 during the March, 1977, survey. Three groundwater samples were collected during the 1979 surveys at locations shown in Fig. 9. The samples were collected in plastic bottles and returned to ORNL for processing. The concentrations of ^{210}Pb, ^{226}Ra, ^{230}Th, ^{232}Th, and ^{238}U were determined using radiochemical techniques.

Background Measurements

External gamma radiation levels were measured at locations near, but not influenced by, former Kellex operations and at 14 locations throughout the northern section of New Jersey (Fig. 13, NJ9 through NJ23). At those locations where undisturbed soil was found, surface soil samples were taken and analyzed for ^{226}Ra, ^{232}Th, and ^{238}U using the techniques described above. Also, a water sample (W3) was taken from Newark Bay and was analyzed for ^{210}Pb, ^{226}Ra, ^{230}Th, and ^{238}U using standard radiochemical techniques at the ORNL Analytical Chemistry laboratory.

SURVEY RESULTS

Background Measurements

Background levels of external gamma exposure rates and radionuclide concentration in soil were measured at several locations in northern New Jersey (Fig. 13, location NJ9 through NJ23). The average external gamma exposure rate at 1 m above the surface was 6.1 μR/h and the range of measurements was 4 to 12 μR/h. Soil samples were taken at the same locations and the radionuclide concentrations averaged 1.0 pCi/g of ^{226}Ra, 1.0 pCi/g of ^{232}Th, and 1.2 pCi/g of ^{238}U.

Site Survey*

External gamma radiation

The exposure rate from external gamma radiation measurements during the March, 1977, survey at 1 m above the surface of the site averaged 6.6 μR/h, with a range of 4 to 11 μR/h. These values are the result of 133 individual measurements taken on the site on the grid points as shown in Fig. 8. The individual measurements are given in Table 1. The measurements were not significantly different from normal background for this region of the United States.

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*All values presented in this report include background radiation levels and concentrations.

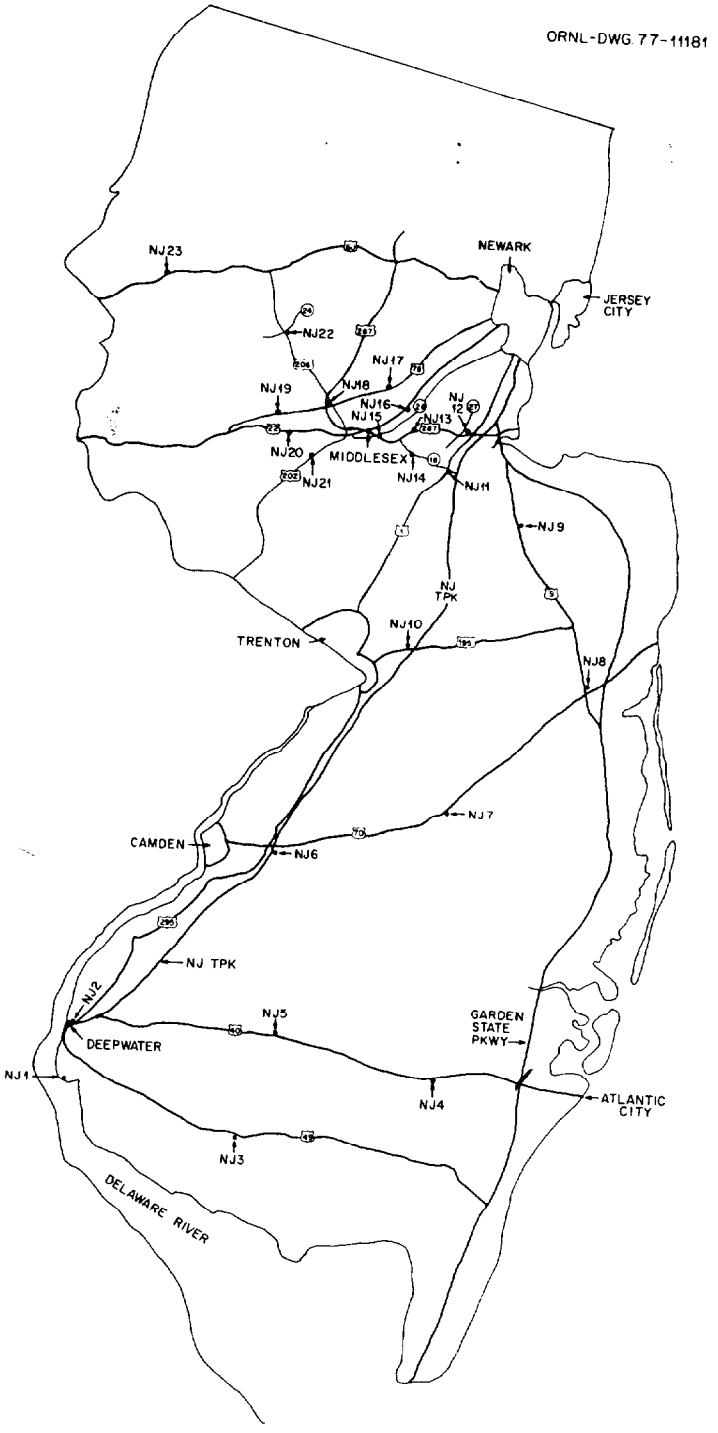

Fig. 13. Location of background measurements in the state of New Jersey.

Table 1. External gamma radiation levels at 1 m above the surface of the Kellex site during March, 1977, survey

Grid location[a]	Exposure rate (μR/hr)	Grid location[a]	Exposure rate (μR/h)	Grid location[a]	Exposure rate (μR/h)
A10	7	F 1	7	I 1	7
A11	7	F 2	8	I 2	8
A12	7	F 3	8	I 3	8
A13	8	F 4	8	I 4	4
		F 5	7	I 5	4
B 3	6	F 6	5	I 6	4
B 4	8	F 7	4	I 7	4
B 5	9	F 8	4	I 8	4
B 6	8	F 9	9	I 9	4
B 7	5	F10	7	I10	5
B 8	5	F11	8	I11	5
B 9	10	F12	7	I12	6
B10	10	F13	8	I13	8
B11	8				
B12	9	G 1	7	J 1	7
B13	8	G 2	4	J 2	6
		G 3	5	J 3	5
C 3	9	G 4	4	J 4	6
C 4	6	G 5	4	J 5	6
C 5	6	G 6	4	J 6	5
C 6	8	G 7	4	J 7	6
C 7	5	G 8	4	J 8	4
C 8	6	G 9	5	J 9	6
C 9	7	G10	7	J10	4
C10	7	G11	5	J11	6
C11	6	G12	6	J12	6
C12	8	G13	8		
C13	8			K 1	7
		H 1	7	K 2	8
D 1	7	H 2	6	K 3	7
D 2	10	H 3	6	K 4	7
D 3	11	H 4	6	K 5	7
D 4	11	H 5	6	K 6	8
D 5	9	H 6	6	K 7	6
D 6	9	H 7	4	K 8	7
D 7	9	H 8	6	K 9	7
D 8	6	H 9	6		
D 9	8	H10	6	L 3	7
D10	7	H11	6	L 4	7
D11	7	H12	6	L 5	7
D12	9	H13	8	L 6	7
D13	8			L 7	8
				M 5	7
E 1	7			M 6	7
E 2	8				
E 3	7				
E 4	7				
E 5	6				
E 6	6				
E 7	7				
E 8	6				
E 9	7				
E10	5				
E11	7				
E12	7				
E13	8				

[a] See Fig. 7 for grid location on site property.

External gamma exposure rate measurements were made at the ground surface in the 1979 surveys so that areas having exposure rates significantly above background were more easily identified. The property that was gamma-ray scanned during the 1979 surveys is shown in Fig. 11. Exposure rates at the ground surface ranged from approximately 6.7 μR/h to 16 μR/h and averaged approximately 11 μR/h. Large areas on the site were covered by a cinder-type fill material. Exposure rates over these areas averaged higher than on other site locations (approximately 15 μR/h) and values as high as 19 μR/h were observed.

During the March, 1977, survey, external gamma-ray measurements revealed only two areas (Area 1 and Area 2, see Fig. 11) of significant contamination on the concrete pad where Building 11 existed (see section on Survey of Building 11 Concrete Pad). During the 1979 surveys, seven additional areas were found (Areas 3-9) having significantly higher-than-background external gamma exposure rates. The location, size, and maximum external gamma exposure rate at ground surface for all nine areas found during 1977 and 1979 surveys are listed in Table 2.

The following description relates the nine areas of interest with buildings that were present during MED/AEC operations on the former Kellex site (refer to Figs. 6 and 9 for locations). Area 1 is situated on or near the former Building 24. Areas 2, 3, and 4 are situated on or adjacent to the location of former Building 11. Area 5 is situated on or near former Building 10, and Area 6 is located to the north of former Building C including the north half of that building. Area 7 is located where the south part of Building C was located. Area 8 is located between the former Buildings A and D, and Area 9 is located southeast of former Building A where no buildings were located. Only Buildings 11 and A reportedly contained the experimental gaseous diffusion operations.*

*The use of Buildings B, C, and D is unknown but they may have been used in supporting functions for gaseous diffusion research. Thus, Areas 1, 5, and 9 could have become contaminated by post-MED use of the facilities, or by demolition and relocation of material from other contaminated structures or soils.

Table 2. Location, size, and maximum gamma exposure rate measurement (at ground surface) in areas of low-level contamination

Area[a]	Size (m)	Maximum external gamma exposure rate observed on ground surface (μR/h)
1	11 x 13	53
2	12 x 16	210
3	9 x 13	160
4	7.3 x 11	110
5	1.0 x 1.0	40
6	30 x 91	130
7	6.1 x 6.1	27
8	3.7 x 9.1	27
9	1.8 x 7.6	53

[a]Location of areas at Kellex site shown on Fig. 9.

Beta-gamma dose rates

During the March, 1977, survey, the beta-gamma dose rates at 1 cm above the surface averaged 0.02 mrad/h over the site with a range of 0.01 to 0.09 mrad/h. These values are the result of 113 individual measurements taken on most of the grid points shown in Fig. 7. The individual measurements are given in Table 3. The values obtained were not significantly different from expected background beta-gamma dose rates for this region of the United States. During the 1979 surveys, beta-gamma measurements were made to assist in defining the location and extent of those areas containing low-level contamination.

Radionuclide concentrations in surface soil

Soil samples were obtained from the site at the locations shown in Fig. 8 during the March, 1977, survey. The results of the radionuclide analyses of these samples are given in Table 4. A total of 31 samples were obtained from the general site; samples 32 through 36 were from the concrete pad area of former Building 11. Samples 32 and 36 were from old building drains, while samples 33 through 35 were scrapings from areas giving elevated radiation readings on the survey meters. The results of samples taken on the concrete pad will be discussed in the section dealing with the survey of this structure. A discussion of the results of the other samples follows.

In the 31 samples which were representative of the general site, the ^{226}Ra concentration averaged 1.2 pCi/g with a range of 0.29 to 2.4 pCi/g. The concentration of ^{232}Th averaged value 1.2 pCi/g with a range of 0.50 to 2.3 pCi/g, and the ^{238}U concentration averaged 1.2 pCi/g with a range of 0.34 to 3.3 pCi/g.

During the 1979 surveys, soil samples (and one concrete sample – K45) were obtained exclusively from Area 1 through Area 9 where elevated external gamma-ray measurements were observed. The single exception being sample K94 (Fig. 9), which was a cinder sample. This sample was obtained because elevated external gamma-ray measurements were observed above those locations covered by the cinder material.

Table 3. Beta-gamma dose rates at 1 cm above the surface of the Kellex site

Grid location[a]	Dose rate (mrad/h)	Grid location[a]	Dose rate (mrad/h)	Grid location[a]	Dose rate (mrad/h)
A12	0.02	E 6	0.01	I 1	0.02
		E 7	0.02	I 2	0.02
B 3	0.01	E 8	0.01	I 3	0.02
B 4	0.03	E 9	0.01	I 4	0.01
B 5	0.02	E10	0.01	I 5	0.01
B 6	0.04	E11	0.02	I 6	0.02
B 7	0.09	E12	0.03	I 7	0.02
B 8	0.02			I 8	0.02
B 9	0.03	F 1	0.02	I 9	0.01
B10	0.04	F 2	0.03	I10	0.03
B11	0.03	F 3	0.03	I11	0.02
B12	0.04	F 4	0.03	I12	0.02
		F 5	0.03		
C 3	0.02	F 6	0.02	J 1	0.02
C 4	0.02	F 7	0.02	J 2	0.02
C 5	0.02	F 8	0.02	J 3	0.02
C 6	0.02	F 9	0.02	J 4	0.02
C 7	0.01	F10	0.03	J 5	0.03
C 8	0.01	F11	0.02	J 6	0.02
C 9	0.02	F12	0.03	J 7	0.02
C10	0.02			J 8	0.02
C11	0.02	G 1	0.02	J 9	0.03
C12	0.03	G 2	0.02	J10	0.01
		G 3	0.01	J11	0.02
D 1	0.02	G 4	0.02		
D 2	0.02	G 5	0.02	K 1	0.02
D 3	0.02	G 6	0.02	K 2	0.03
D 4	0.02	G 7	0.01	K 3	0.05
D 5	0.03	G 8	0.02	K 4	0.03
D 6	0.02	G 9	0.02	K 5	0.02
D 7	0.03	G10	0.02	K 6	0.01
D 8	0.02	G11	0.01	K 7	0.02
D 9	0.04	G12	0.02	K 8	0.02
D10	0.03			K 9	0.02
D11	0.04	H 1	0.02		
D12	0.03	H 2	0.02	L 3	0.02
		H 3	0.02	L 4	0.03
		H 4	0.02	L 5	0.02
		H 5	0.02	L 6	0.02
		H 6	0.02	L 7	0.02
		H 7	0.02		
		H 8	0.02		
		H 9	0.02		
		H10	0.02		
		H11	0.02		
		H12	0.02		

[a]See Fig. 7 for grid location on the site property.

Table 4. Radionuclide concentrations in soil and drain pipe scale samples from the March, 1977, survey

Sample	Depth (cm)	Radionuclide concentrations (pCi/g)		
		^{238}U	^{226}Ra	^{232}Th[a]
K1	0-7.5	1.8	1.7 ± 0.04	1.5 ± 0.35
K2	0-2.5	0.64	0.69 ± 0.01	0.74 ± 0.01
K3	0-1	0.57	0.75 ± 0.06	0.69 ± 0.02
K4	0-1	0.70	0.72 ± 0.02	0.91 ± 0.03
K5	0-7.5	0.34	0.29 ± 0.03	0.50 ± 0.01
K6	0-7.5	1.8	2.0 ± 0.03	2.0 ± 0.04
K7	0-7.5	0.73	0.74 ± 0.01	0.98 ± 0.02
K8	0-7.5	0.54	0.50 ± 0.02	0.64 ± 0.03
K9	0-7.5	1.3	1.2 ± 0.03	1.3 ± 0.04
K10	0-5	0.85	0.79 ± 0.02	1.0 ± 0.02
K11	0-5	0.80	0.87 ± 0.05	0.8 ± 0.06
K12	0-7.5	0.99	0.92 ± 0.03	1.0 ± 0.03
K13	0-7.5	0.47	0.50 ± 0.04	0.50 ± 0.01
K14	0-7.5	1.1	1.2 ± 0.03	1.3 ± 0.03
K15	0-7.5	0.70	0.65 ± 0.02	0.85 ± 0.03
K16	0-5	0.45	0.23 ± 0.02	0.55 ± 0.02
L17	0-5	0.71	0.57 ± 0.02	0.75 ± 0.10
K18	0-7.5	1.1	1.2 ± 0.02	1.3 ± 0.05
K19	0-5	0.86	1.1 ± 0.08	0.91 ± 0.01
K20	0-7.5	1.9	2.4 ± 0.09	1.0 ± 0.04
K21	0-5	1.1	0.75 ± 0.02	0.83 ± 0.01
K22	0-7.5	1.6	1.9 ± 0.08	1.7 ± 0.05
K23	0-5	1.7	1.5 ± 0.05	1.5 ± 0.05
K24	0-7.5	1.6	1.8 ± 0.06	1.9 ± 0.04
K25	0-7.5	1.2	1.2 ± 0.04	1.3 ± 0.04
K26	0-5	1.2	1.3 ± 0.05	1.2 ± 0.04
K27	0-5	1.2	1.4 ± 0.03	1.3 ± 0.05
K28	0-7.5	1.6	1.9 ± 0.08	1.4 ± 0.35
K29	0-7.5	1.3	1.3 ± 0.04	1.5 ± 0.04
K30	0-7.5	3.3	1.6 ± 0.02	1.7 ± 0.04
K31	0-7.5	2.2	2.4 ± 0.04	2.3 ± 0.03
K32	Drain pipe	0.64	1.1 ± 0.12	0.82 ± 0.08
K33	0-5	11	110 ± 1.2	110 ± 1.5
K34	0-5	29	150 ± 5.1	[b]
K35	0-5	14	54 ± 0.81	270 ± 1.8
K36	Drain pipe	0.58	0.83 ± 0.04	1.3 ± 0.08

[a] Indicated statistical counting errors associated with these concentrations are two standard deviations (95% confidence interval).

[b] Radionuclide concentration was below minimum detectable concentration.

Results of the soil sample radionuclide analyses for the 1979 surveys are listed in Table 5. Maximum radionuclide concentrations observed on the Kellex site for ^{238}U, ^{226}Ra, and ^{232}Th were 2,100 pCi/g (K80 - Area 6), 340 pCi/g (K39 - Area 2), and 4,300 pCi/g (K41A - Area 1), respectively.

Radium-226 concentrations in subsurface soil

In the 1979 surveys, 27 holes were drilled at various locations on the Kellex site so that estimates of subsurface concentrations of ^{226}Ra in soil could be made. The ^{226}Ra concentration estimates for each of the 27 holes are listed in Table 6. The location of the holes is shown in Fig. 12. The estimates ranged from 0.45 pCi/g (KC27 at 0 cm depth) to 7.7 pCi/g (KC23 at 46 cm depth) of ^{226}Ra in soil, and averaged 1.5 pCi/g.

In two holes (KC19 and KC23) core soil samples were collected and analyzed for radionuclide content. The results of these analyses are listed in Table 7, for grid locations again identified in Fig. 12. Most radionuclide concentrations were elevated above background activity, but not significantly so, with the exception of sample KC19D with a ^{238}U concentration of 8.5 pCi/g of soil.

Three trenches were dug by heavy equipment in and around Area 6. Soil samples were collected at variable depths and analyzed for radionuclide content. Results of analyses are listed in Table 8 and locations of sampling sites are indicated in Fig. 9. Higher-than-background concentrations of ^{238}U or ^{226}Ra were observed in all three trenches at varying depths.

Radionuclide concentrations in water

Water samples were obtained during the March, 1977, survey from three locations on the site as shown in Fig. 8. In addition, one sample (W3) was taken from Newark Bay in the vicinity of the former Kellex site. The results of the radionuclide analyses are presented in Table 9. For the sake of comparison, the Radiation Concentration

Table 5. Radionuclide concentrations in soil samples taken during the 1979 surveys

Sample	Location[a]	Sample type	Depth (cm)	Radionuclide concentrations (pCi/g)[b]		
				^{238}U	^{226}Ra	^{232}Th
K37	Grid D7 (Area 3)	Soil	0-8[c]	5.7	270 ± 2.5	7.4 ± 1.3
K38	Grid A19 (Area 2)	Soil	Beneath 20 cm of concrete	0.71	0.68 ± 0.054	0.61 ± 0.030
K39	Grid A17 (Area 2)	Soil	0-8	11	340 ± 2.4	98 ± 1.3
K40	Area 1	Soil	10	41	*d*	2500 ± 38
K41	Area 1	Soil	15	56	*d*	3000 ± 35
K41A	Area 1	Soil	15	72	*d*	4300 ± 47
K42	Area 1	Soil	20	9.1	0.77 ± 0.050	16 ± 0.14
K43	Area 1	Soil	0-8	2.2	1.7 ± 0.080	21 ± 0.22
K44	Area 1	Soil	0-8	0.91	*d*	15 ± 0.28
K45	Area 2	Concrete	--	1.2	0.98 ± 0.018	1.8 ± 0.034
K46	4+00, 100R (Area 4)	Soil	0-8	1.5	2.6 ± 0.15	1.3 ± 0.040
K47	Area 4	Soil	0-8	2.4	13 ± 0.20	1.6 ± 0.080
K48	Area 4	Soil	0-8	2.2	4.0 ± 0.20	1.5 ± 0.080
K49	Area 4	Soil	0-8	2.7	3.4 ± 0.030	2.4 ± 0.050
K50	Area 4	Soil	0-8	2.0	4.1 ± 0.12	4.1 ± 0.12
K51	Area 4	Soil	0-8	2.2	9.2 ± 0.27	1.4 ± 0.18
K52	Area 4	Soil	0-8	1.7	2.6 ± 0.67	2.0 ± 0.60
K53	Area 4	Soil	0-8	1.7	1.4 ± 0.24	1.0 ± 0.12
K74	8+25, 430R (Area 6)	Soil	0-8	1.1	*d*	58 ± 0.73
K75	8+25, 320R (Area 6)	Soil	0-8	930	1.5 ± 0.26	1.5 ± 0.16
K76	7+50, 400R (Area 6)	Soil	0-8	5.6	*d*	94 ± 1.2
K77	8+30, 330R (Area 6)	Soil	0-8	79	1.7 ± 0.040	2.0 ± 0.010
K78	8+30, 330R (Area 6)	Soil	0-8	66	1.2 ± 0.040	1.2 ± 0.040
K79	8+30, 345R (Area 6)	Soil	0-8	810	2.0 ± 2.8	1.8 ± 0.63
K80	8+40, 398R (Area 6)	Soil	0-15	2100	*d*	*d*
K85	5+80, 145R (Area 5)	Soil	0-8	4.5	*d*	210 ± 2.4
K89	8+50, 350R (Area 6)	Soil	0-8	1300	2.0 ± 0.18	2.1 ± 0.18
K90	8+53, 48R (Area 8)	Soil	13-38	870	*d*	*d*
K91	8+75, 230R (Area 7)	Soil	0-8	110	2.3 ± 5.3	2.2 ± 7.8
K92	8+85, 235R (Area 7)	Soil	20	2.4	2.8 ± 0.027	2.9 ± 0.041
K93	Area 9	Soil	0-15	1.2	100 ± 0.65	1.8 ± 0.25
K94	8+40, 230L	Cinders	0-15	2.1	2.4 ± 0.94	2.5 ± 0.09

[a] Sample and area location is shown in Fig. 9.

[b] Indicated errors associated with these concentrations are two standard deviations (95% confidence interval).

[c] A depth of 0-8 cm was considered a surface sample.

[d] Radionuclide concentration was below minimum detectable concentration.

Table 6. Estimated ^{226}Ra concentration in soil as a function of depth at drill hole locations at the Kellex site

Sample	Grid location[a] (ft)	Estimated ^{226}Ra concentration in soil (pCi/g) Depth (m) 0	0.30	0.61	0.91	1.2	1.5	1.8	2.1	2.4	2.7	3.0	Remarks
KC 1	4+00, 100R[b]	0.95	2.1	1.9	1.8	0.76	0.83	0.92	0.85	0.79	0.80		
KC 2	5+50, 100R	1.3	1.6	1.8	2.2	1.8	1.7						
KC 3	7+00, 200R	1.6	2.1	2.5	1.8	1.1	1.4						
KC 4	5+00, 200R	1.0	1.1	1.0	1.4	1.3	1.5	1.6	1.2	1.1	1.1		
KC 5	3+00, 200R	1.2	1.6	1.7	1.7	1.1	0.83	0.93					
KC 6	1+00, 200R	1.7	1.9	1.7	1.2	1.2	1.2	1.3	1.6	1.7	1.7		
KC 7	4+00, 300R	1.2	1.6	1.5	1.3	1.0	0.95	0.49	1.1				
KC 8	6+00, 300R	1.1	1.6	1.5	1.1	1.1	0.93	1.4					
KC 9	7+00, 400R	1.3	2.2	2.1	1.5	1.7	1.7	1.7	1.8	1.4			
KC10	5+00, 400R	0.92	1.1	1.1	0.95	1.0	1.1	0.93	0.94				
KC11	6+00, 500R	1.4	2.0	1.2	1.3	1.1	1.2	1.0					
KC12	3+00, 100R	0.95	1.1	1.4	2.0	1.7	1.6	1.3	1.1	0.89	0.87		
KC13	3+00, 50R	0.55	1.1	1.4	1.2	1.2	1.4	1.4					Below concrete of Bldg. 11 pad
KC14	3+15, 15L	1.4	2.6	2.4	2.0	1.7	1.4	1.3	1.6				
KC15	3+30, 30L	1.0	1.6	1.7	1.6	1.5	1.6	1.4	1.3				
KC16	3+36, 30L	1.2	1.7	2.0	1.7	1.7	1.5	1.5	1.1	0.86			
KC17	3+65, 70L	0.75	1.1	1.1	1.3	1.1	1.0	0.99	1.5	1.7			
KC18	5+50, BL	1.1	1.9	1.7	1.6	1.8	1.2	1.7	1.9	2.0			
KC19	4+50, BL	0.95	1.4	2.2	2.2	1.9	1.6	1.6	1.3	1.1			
KC19A	4+50, BL	0.93	1.6	2.4	2.1	1.8	1.8	1.8					Core hole 1.5 m right of KC19
KC20	2+00, 100R	1.0	1.7	1.3	1.7	1.7	1.6	1.8					
KC21	2+10, BL	1.1	1.5	1.6	2.1	2.2	1.9	1.6	1.5	1.6	1.4	1.2	
KC22	2+30, 40L	1.4	1.8	1.4	1.9	1.9	1.8	1.9	1.9	1.6	1.4		
KC23	2+30, 32L	1.6	5.2	3.3	2.8	2.6	2.3	2.3	1.6	1.6			
KC23	2+30, 32L	@ 0.5 ft: 2.6 pCi/g; @ 1.5 ft: 7.7 pCi/g; @ 2.5 ft: 2.8 pCi/g											
KC24	1+00, 100R	0.90	1.2	1.2	1.1	1.3	1.2	1.2	1.4				
KC25	0+ 8, 65R	0.69	0.94	1.0	0.96	0.87	1.3	1.4	1.1	0.92	1.0	1.3	Below concrete of Bldg. 24 pad
KC26	0+ 5, 55R	0.91	1.5	1.1	0.90	0.89	1.1	1.4	1.4	1.5	1.3	1.0	
KC27	0+ 5, 50R	0.45	0.91	1.0	1.1	0.88	0.96	1.6	1.5	1.2	1.1	1.2	

[a] Location is identified in Fig. 12.

[b] R = right of base line; L = left of base line; BL = on base line.

Table 7. Radionuclide content of core samples from the Kellex site

Sample	Location[a]	Depth (cm)	Radionuclide concentrations (pCi/g)[b]		
			^{238}U	^{226}Ra	^{232}Th
KC19A	4+50, BL	0-3	0.69	0.61 ± 0.010	0.82 ± 0.030
KC19B	4+50, BL	3-5	0.84	1.1 ± 1.5	1.2 ± 4.9
KC19C	4+50, BL	5-8	1.9	2.1 ± 0.030	2.1 ± 0.040
KC19D	4+50, BL	8-10	8.5	3.6 ± 0.060	2.0 ± 0.040
KC19E	4+50, BL	10-13	2.0	2.1 ± 0.030	2.1 ± 0.040
KC19F	4+50, BL	13-18	1.7	1.8 ± 0.030	1.7 ± 0.040
KC23A	2+30, 32L	0-46	0.70	0.67 ± 0.010	0.82 ± 0.020

[a]Grid location may be identified in Fig. 12.

[b]Indicated errors associated with these concentrations are two standard deviations.

Table 8. Radionuclide concentrations in soil taken from trenches on Kellex site during 1979 surveys

Sample[a]	Depth (cm)	Radionuclide concentrations (pCi/g)[b]		
		^{238}U	^{226}Ra	^{232}Th
KT11A	0-20	5.4	1.4 ± 0.020	1.4 ± 0.020
KT11B	90	2.2	2.4 ± 0.030	2.3 ± 0.040
KT11C	180	0.31	0.37 ± 0.010	0.57 ± 0.020
KT12A	0-30	5.1	1.8 ± 0.020	1.6 ± 0.040
KT12B	90	1.9	1.6 ± 0.030	1.6 ± 0.030
KT12C	180	0.34	0.43 ± 0.010	0.54 ± 0.020
KT13A	0-30	1.6	1.7 ± 0.027	1.6 ± 0.035
KT13B	30-46	4.6	9.1 ± 0.090	4.0 ± 0.060
KT13C	180	0.55	0.52 ± 0.020	0.66 ± 0.020

[a]Locations are shown in Fig. 9.

[b]Indicated errors associated with these concentrations are two standard deviations.

Table 9. Radionuclide concentrations in water samples during March, 1977, survey

Sample	Radionuclide concentrations (pCi/L)[a]			
	^{210}Pb	^{226}Ra	^{230}Th	^{238}U
W1	1.1 ± 0.58	0.032 ± 0.036	0.086 ± 0.036	1.2 ± 0.09
W2	<0.77	0.13 ± 0.09	0.022 ± 0.022	0.63 ± 0.22
W3	0.18 ± 0.67	0.027 ± 0.045	0.045 ± 0.045	0.90 ± 0.045
W4	<0.86	0.13 ± 0.09	0.045 ± 0.022	0.21 ± 0.01
RCG_w	100	30[b]	2,000	40,000

[a] Indicated errors associated with these concentrations are two standard deviations.

[b] The EPA drinking water standard for radium is 5 pCi/L, including both ^{226}Ra and ^{228}Ra.

Guide in water* (RCG_W) for nonoccupational exposure[3] is also given in Table 9. The concentrations of ^{210}Pb, ^{226}Ra, ^{230}Th, and ^{238}U are all at least an order of magnitude less than the corresponding RCG_W. The radium concentrations are also at least an order magnitude lower than the Environmental Protection Agency's (EPA) drinking water standard for radium.[4]

Three water samples were obtained during the 1979 surveys from locations shown in Fig. 9. Results of radionuclide analyses are listed in Table 10. All concentrations were one to several orders of magnitude less than the radiation concentration guides for these radionuclides in water.

Building surveys

A radiological survey was conducted in the machine shop (Fig. 7) during the March, 1977, survey. For 29 readings of external gamma radiation, the average exposure rate was 5 μR/h and the average beta-gamma dose rate was 0.03 mrad/h. These levels were nearly uniform throughout the building. All direct measurements of alpha contamination indicated <100 dpm/100 cm^2.

The radiological survey of the garage (Fig. 7) yielded gamma-ray exposure rates of 5 to 6 μR/h at 1 m and an average beta-gamma dose rate of 0.03 mrad/h at 1 cm for 12 measurements of each. The direct alpha contamination levels were all <100 dpm/100 cm^2.

Radiation measurements were made at 88 locations in Building X (Fig. 7). The average gamma exposure rate at 1 m was 6 μR/h and the average beta-gamma dose rate at 1 cm was 0.02 mrad/h. Both the exposure rates and dose rates were nearly uniform throughout the building. Again, all direct readings of alpha contamination indicated <100 dpm/100 cm^2.

At the time of the 1979 surveys, the buildings indicated in Fig. 7 had been removed from the site.

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*This is also commonly referred to as maximum permissible concentration (MPC_W) (c.f. NCRP Report No. 22, 1959).

Table 10. Radionuclide concentrations in water samples collected during the 1979 surveys

Sample[a]	Radionuclide concentrations (pCi/L)[b]				
	^{210}Pb	^{226}Ra	^{230}Th	^{238}U	^{232}Th
KTW11	<9.0	0.45 ± 0.45	0.90 ± 0.90	9.3 ± 1.9	0.90 ± 0.90
KTW12	<9.0	0.45 ± 0.45	0.45 ± 0.45	3.3 ± 1.7	0.45 ± 0.45
KTW13	<9.0	0.45 ± 0.45	1.4 ± 1.4	1.0 ± 1.0	1.4 ± 1.4
RCG_W	100	30[c]	2,000	40,000	2,000

[a]Locations of samples shown in Fig. 9.

[b]Indicated errors associated with these concentrations are two standard deviations.

[c]The EPA drinking water standard for radium is 5 pCi/L, including both ^{226}a and ^{228}Ra.

Survey of Building 11 concrete pad

A thorough radiological survey was conducted in the area formerly occupied by Building 11, the old Kellex Laboratory, during the March, 1977, survey. All that remained of this structure was a concrete pad, located as shown in Fig. 7. During the 1979 surveys, much of this concrete pad had been removed as a result of site development.

The results of the alpha and beta-gamma contamination surveys are given in Table 11. The survey locations for these measurements are shown by the grid blocks in Fig. 10. The direct readings of alpha contamination, when averaged over 1 m^2, were all less than 30 dpm/ 100 cm^2. One spot of 100 cm^2 in grid block A19 (Fig. 10) gave an alpha reading of 3,000 dpm/100 cm^2. The beta-gamma dose rates when averaged over 1 m^2 were generally less than 0.03 mrad/h. Three exceptions were grid blocks B19, E5, and F6 which had beta-gamma dose rates of 0.14, 0.05, and 0.05 mrad/h, respectively. Significantly higher activity was found in one area of 100 cm^2 in grid block A19 where a beta-gamma dose rate of 0.6 mrad/h was measured. Also, one area in grid block B6 had a beta-gamma dose rate of 0.04 mrad/h.

The results of measurements of transferable alpha and beta contamination are also given in Table 11. The transferable alpha contamination, when averaged over 1 m^2, was always less than 20 dpm/100 cm^2, and the beta contamination was always less than 200 dpm/100 cm^2 when averaged in the same manner. One area of 100 cm^2 in grid section A19 had smear readings (smear located by an asterisk in Fig. 14) of 330 dpm/100 cm^2 alpha and 310 dpm/100 cm^2 beta-gamma.

The external gamma radiation level was measured at 1 m above the floor surface at each of the grid intersections in Fig. 10. For the total of 105 readings, the average exposure rate was 6.6 μR/h, with a range of 5 to 12 μR/h. The individual gamma-ray measurements are presented in Table 12.

Most of the grid sections identified in Fig. 14 had radiation and contamination levels near background. However, readings from a few grid sections were elevated. In grid section B6, maximum readings of 23 μR/h gamma and 0.04 mrad/h beta-gamma at 1 cm above the surface were

Table 11. Alpha and beta-gamma levels on the concrete pad of former Kellex Laboratory Building 11

Grid location[a]	Direct reading[b]		Transferable contamination[c]	
	Alpha (dpm/100 cm^2)	Beta-gamma (mrad/h)	Alpha (dpm/100 cm^2)	Beta-gamma (dpm/100 cm^2)
A 1	<30	<0.03	4	0
A 2	<30	<0.03	0	34
A 5	<30	<0.03	4	34
A 7	<30	<0.03	0	86
A 9	<30	<0.03	0	86
A11	<30	<0.03	0	69
A13	<30	<0.03	0	69
A15	<30	<0.03	9	17
A17	<30	<0.03	0	0
A19	<30 3000[d]	<0.03 0.6[d]	0 326[d]	17 310[d]
B 2	<30	<0.03	0	52
B 4	<30	<0.03	0	172
B 6	<30	<0.03 0.04[d]	4	0
B 8	<30	<0.03	0	103
B10	<30	<0.03	0	0
B12	<30	<0.03	4	0
B14	<30	<0.03	0	0
B16	<30	<0.03	0	0
B18	<30	<0.03	4	0
B19	<30	0.14	--	--
B20	<30	<0.03	0	0
C 1	<30	<0.03	4	0
C 3	<30	<0.03	9	0
C 5	<30	<0.03	0	103
C 7	<30	<0.03	4	138
C 9	<30	<0.03	0	0
C11	<30	<0.03	0	0
C13	<30	<0.03	0	0
C15	<30	<0.03	4	86
C17	<30	<0.03	4	52
C19	<30	<0.03	0	0
D12	<30	<0.03	0	34
D14	<30	<0.03	0	0
D16	<30	<0.03	0	0
E 5[e]	<30	0.05	--	--
E11	<30	<0.03	0	34
E13	<30	<0.03	0	0
E15	<30	<0.03	0	0
F 6[e]	<30	0.05	--	--
F12	<30	<0.03	0	0
F14	<30	<0.03	0	52
F16	<30	<0.03	0	120

[a] See Fig. 10 for grid locations.

[b] Direct readings are averaged over 1 m^2 (unless otherwise indicated) in the respective grid block. Beta-gamma dose rates are measured at 1 cm above the surface.

[c] Transferable contamination measurements are averaged over 1 m^2 (unless otherwise indicated) in the respective grid block. A zero measurement indicates a smear count less than or equal to background.

[d] This represents a maximum reading averaged over not more than 100 cm^2

[e] This location is not on the concrete pad proper but is on the ground near the pad.

Table 12. External gamma-ray exposure rate at 1 m above the concrete pad of former Kellex Laboratory Building 11

Grid location[a]	Exposure rate (μR/h)	Grid location[a]	Exposure rate (μR/h)	Grid location[a]	Exposure rate (μR/h)
A 1	6	C 1	6	E11	6
A 2	6	C 2	5	E12	5
A 3	6	C 3	6	E13	5
A 4	6	C 4	6	E14	5
A 5	6	C 5	6	E15	5
A 6	5	C 6	5	E16	5
A 7	6	C 7	5	E17	5
A 8	6	C 8	5		
A 9	6	C 9	6	F11	5
A10	5	C10	5	F12	6
A11	5	C11	5	F13	6
A12	5	C12	5	F14	5
A13	5	C13	5	F15	5
A14	5	C14	5	F16	5
A15	5	C15	5	F17	6
A16	5	C16	5		
A17	6	C17	6	G11	5
A18	7	C18	7	G12	5
A19	9	C19	7	G13	5
A20	5	C20	12	G14	6
A21	5	C21	7	G15	5
				G16	5
B 1	6	D 1	7	G17	6
B 2	6	D 2	7		
B 3	6	D 3	6		
B 4	5	D 4	6		
B 5	6	D 5	6		
B 6	5	D 6	5		
B 7	5	D 7	5		
B 8	5	D 8	6		
B 9	5	D 9	6		
B10	5	D10	6		
B11	5	D11	6		
B12	5	D12	5		
B13	5	D13	5		
B14	5	D14	5		
B15	5	D15	5		
B16	5	D16	5		
B17	8	D17	5		
B18	9	D18	6		
B19	8	D19	6		
B20	9	D20	6		
B21	7	D21	7		

[a]See Fig. 10 for grid point locations.

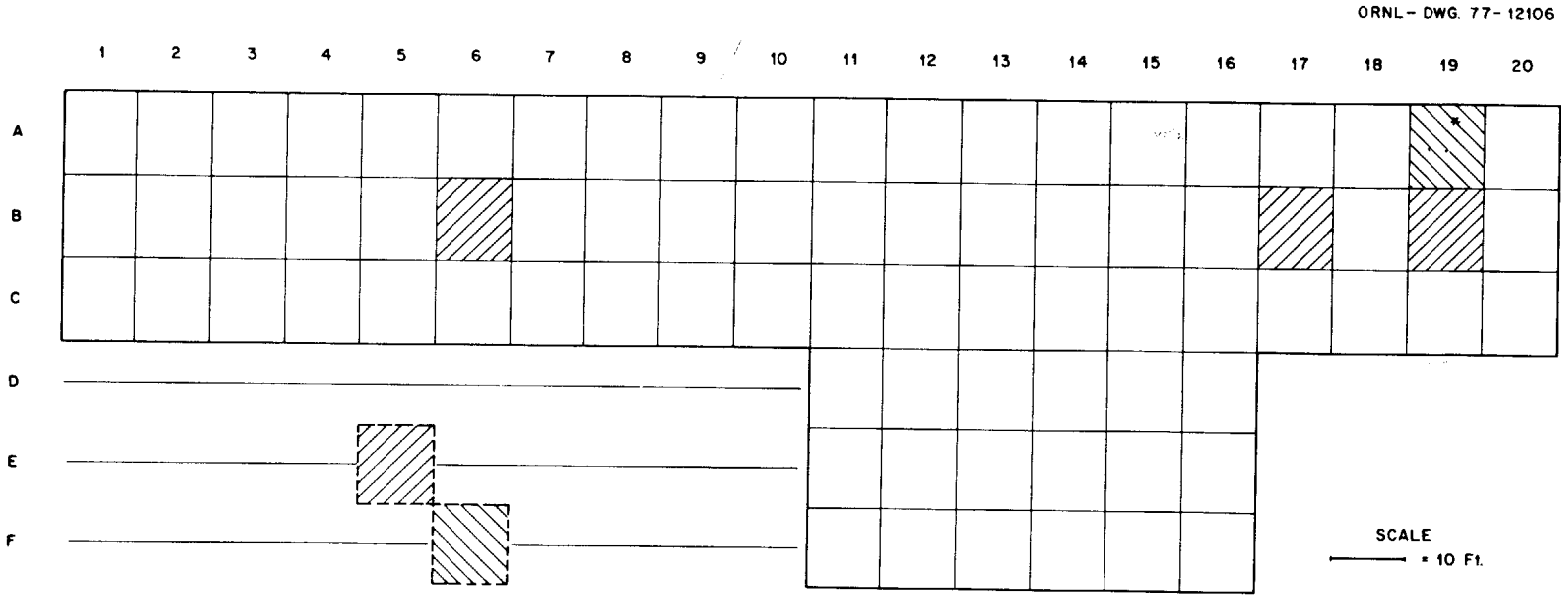

Fig. 14. Concrete pad areas of former Building 11 (contaminated areas are shaded).

measured. The readings in grid section B17 indicated a maximum gamma-ray exposure rate of 72 μR/h at the surface. In grid section B19, the beta-gamma dose rate averaged 0.14 mrad/h over a 1-m^2 area, and the maximum gamma-ray exposure rate was 110 μR/h at the surface. The highest radiation measurements on the concrete pad were found in grid section A19. The maximum readings here were 3,000 dpm/100 cm^2 alpha, 0.6 mrad/h beta-gamma, and 136 μR/h gamma at the surface. Three samples of dirt (samples 33 to 35 in Table 4) were scraped from section A19. These samples had elevated concentrations of the measured radionuclides. The fact that these measurements are at elevated levels indicates that some kind of uranium- and thorium-bearing materials were probably stored or handled at this isolated spot of section A19 at some previous time. The drain pipe scale samples (K32 and K36) showed no elevated radionuclide concentrations.

Radiation measurements taken in the area surrounding the concrete pad for former Building 11 were essentially background, with the exception of one small area located in grid sections E5 and F6 (Fig. 14). In section E5, the beta-gamma dose rate averaged 0.05 mrad/h and gamma exposure rates averaged 18 μR/h at the surface over a 1-m^2 area. In section F6, maximum readings of 0.8 mrad/h beta-gamma and 80 μR/h gamma were measured at the surface.

The two areas where elevated activity was observed during the March, 1977, survey were redesignated in the 1979 surveys. Grid section A19 was enlarged and called Area 2, and grids E5 and F6 were consolidated into Area 3.

SUMMARY AND CONCLUSIONS

A summary of the survey results is provided in Table 13. Excluding the nine areas noted earlier in this report and identified in Fig. 9, the mean external gamma-ray exposure rates observed on the Kellex site (6.6 μR/h) were similar to those mean background exposure rates observed in northern New Jersey (6.1 μR/h). The exposure guideline for an individual in the general public is 500 mrem/y,[2] which is considerably higher than any conceivable exposure that an individual might receive on the Kellex site.

Table 13. Summary of survey results at the former Kellex Research Facility in Jersey City, New Jersey

Survey technique	Number of measurements or samples taken	Range of values	Arithmetic mean and standard deviaion[a] $\bar{x} \pm s$	Geometric mean and geometric standard[a] deviation $x_g : s_g$
Grid point measurements				
Gamma exposure rate at 1 m (μR/h)[b]	133	4-11	6.6 ± 1.6	6.4:1.3
Beta-gamma dose rate at 1 cm (mrad/h)[c]	113	0.01-0.09	0.02 ± 0.01	0.02:1.5
Soil sampling				
1977 survey (excluding Areas 4-9)[d]				
^{238}U (pCi/g)	34	0.45-29	2.7 ± 5.4	1.3:2.6
^{226}Ra (pCi/g)	34	0.29-150	10 ± 32	1.5:4.1
^{232}Th (pCi/g)	33	0.50-270	13 ± 50	1.5:3.7
1979 survey (Areas 1-9)[e]				
^{238}U (pCi/g)	31	0.71-2100	210 ± 480	12:12
^{226}Ra (pCi/g)	23	0.68-340	33 ± 89	4.1:5.6
^{232}Th (pCi/g)	31	0.61-4300	330 ± 1000	8.0:12
Water sampling				
(1977 and 1979 surveys)[f]				
^{238}U (pCi/L)	7	0.21-1.3	2.4 ± 3.2	1.2:3.4
^{230}Th (pCi/L)	7	0.022-1.4	0.42 ± 0.54	0.16:5.2
^{226}Ra (pCi/L)	7	0.027-0.45	0.24 ± 0.20	0.14:3.4
^{210}Pb (pCi/L)	2	0.18-1.1	[g]	[g]
Concrete pad at location of formerly Building 11[h]				
Direct alpha (dpm/100 cm^2)	42	<30-3000	[g]	[g]
Beta-gamma dose rate at 1 cm (mrad/h)	44	<0.03-0.6	[g]	[g]
Gamma exposure rate at 1 m (μR/h)	105	5-12	6.6 ± 8.7	5.8:1.4
Transferable alpha contamination (dpm/100 cm^2)	40	0-326	9.6 ± 51	[g]
Transferable beta-gamma contamination (dpm/100 cm^2)	40	0-310	42 ± 63	[g]

[a] Standard deviations are 1 σ (± 68%).

[b] See Table 1 for data.

[c] See Table 3 for data.

[d] See Table 4 for data.

[e] See Tables 5 and 8 for data.

[f] See Tables 9 and 10 for data.

[g] Too few values to adequately analyze.

[h] See Tables 11 and 12 for data.

Results of soil and water samples show the radionuclide concentrations are at normal background levels on the site except for samples originating from the nine contaminated areas. The average soil concentrations of radionuclides found on the site, excluding those nine areas, were 1.2 pCi/g of ^{226}Ra, 1.2 pCi/g of ^{232}Th, and 1.2 pCi/g of ^{238}U. These were not statistically different from the background levels found in the northern part of the state of New Jersey. From the nine areas, maximum radionuclide concentrations of ^{238}U, ^{226}Ra, and ^{232}Th in surface soil were 2,100 pCi/g (Area 6), 340 pCi/g (Area 2), and 4,300 pCi/g (Area 1), respectively. Radionuclide concentrations in on-site water samples were at least an order of magnitude below accepted concentration guidelines for drinking water.

The nine areas containing higher-than-background concentrations of radioactive material constitute a total area of approximately 3,350 m^2 (0.83 acre). These areas contain varying mixtures of radionuclides from the uranium and thorium decay chains in concentrations significantly above background exceeding federal guidelines (Appendix V). An evaluation of potential hazard relative to the contamination present in these nine areas is presented in Appendix VI.

REFERENCES

1. Personal communication, Jack Terrel, Oak Ridge Y-12 Plant, Oak Ridge, TN (February 1981).
2 E. B. Wagner and G. S. Hurst, "A Geiger-Mueller Gamma-Ray Dosimeter with Low Neutron Sensitivity," *Health Phys.* 5, 20 (1961).
3. *Code of Federal Regulations*, Title 10, Part 20, "Standards for Protection Against Radiation."
4. *Code of Federal Regulations*, Title 40, Part 141, "Interim Primary Drinking Water Regulations."

APPENDIX I

PREVIOUS RADIOLOGICAL SURVEY OF KELLEX SITE

VITRO CORPORATION OF AMERICA

June 25, 1953

Contamination Status Report
Jersey City Laboratory

A final radiation and contamination survey of the Jersey City Laboratory was made with the purpose of determining the amount of residual contamination remaining after extensive decontamination procedures had been undertaken. Results indicate that the laboratory is free from excessive contamination.

Two (2) reports issued by the New York Office of the Commission, namely, "Status of Building Contamination at Kellex Laboratories" and "Second Contamination and Radiation Survey at Kellex Laboratory" dated September 29, 1949, and December 19, 1949, respectively, were used as guides for establishing standards of radioactive contamination which would not be considered significant as potential health hazards.

A set of specific maximum permissible limits were obtained from an AEC report (NYO-1536), "Decontamination and Survey of Uranium Refinery Plant" as follows:

0.9 mrep/hr - worst contact,
9.6 mrep/hr - worst operating position,
0.3 mrep/hr - average at 3 ft from the floor.

The MPCs for transferable contamination in accessible areas were chosen as 0 alpha d/m/sm* and 1,000 beta d/m/sm.

Summary

With but two exceptions (0.6 mrep/hr in chemical storage area and 0.2 mrep/hr in Laboratory 3), the radiation level in the Jersey City Laboratory is below that reported in "Second Contamination and Radiation Survey at Kellex Laboratory" dated December 19, 1949. In neither instance is the maximum permissible limit of 0.9 mrep/hr at point of worst contact exceeded.

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*Authors believe original report to mean smear where "sm" is an abbreviation.

No transferable alpha or beta-gamma contamination was observed in any of the accessible areas.

The ductwork (not included in Commission survey reported December 1949) leading from the laboratory exhaust hoods in Laboratories 3 and 5 gave evidence of transferable alpha ranging from 300 to 500 d/m/ smear, whereas beta-gamma contamination was negligible. However, we understand from Commission personnel that the ductwork should not be considered an accessible area; therefore, the stringent requirement of "no transferable alpha" would not be applicable.

The contamination in the ductwork is virtually 100% normal uranium. It may be estimated that each contaminated duct contains approximately 100 mg of normal uranium as compared with the established maximum allowable amount of 30 mg of normal uranium within the body.

Survey Methods and Instruments

Each laboratory was surveyed by a random method. The rooms were divided into imaginary squares (ca. 3 ft x 3 ft), and a smear test was made in order to determine levels of transferable contamination. Smears were counted both in an alpha scintillation counter and a beta-gamma geiger counter (end window).

The model 2610 IDL beta-gamma survey meter was used for the radiation survey. Since the only alpha active materials ever used in the laboratory were in normal uranium and pitchblende, the IDL meter, by showing no beta-gamma contamination also indicated no alpha contamination. This instrument was chosen mainly because of its good sensitivity and fast reaction which allowed us to scan large areas in order to spot any localized contamination. All recorded measurements are readings made at the point of worst contact unless otherwise specified.

Survey Results

Laboratories 1 and 2. These laboratories were surveyed on March 6, 1953, previous to occupancy by the M. W. Kellogg Company personnel. The maximum radiation levels observed within the ductwork showed a maximum beta-gamma count of 150 d/m, whereas alpha contamination was found to be negligible. Since the tolerance level of beta-gamma smears is 1,000 β-γ d/m/sm, the beta-gamma contamination

recorded may be considered insignificant. All other radiation readings taken in accessible areas, such as floors, desks, hood surfaces, and fixtures approached normal background of 0.02 mrep/hr. Smears yielded insignificant counts.

Laboratory 3. A final survey in this laboratory indicated a maximum radiation level of 0.2 mrep/hr in hood section B. All smear tests yielded negative results. Ductwork in Laboratory 3 showed maximum transferable contamination levels of 500 α d/m/sm; β-γ contamination within the ductwork was negligible.

Laboratory 4. The maximum radiation level in this laboratory was found in hood section C (0.05 mrep/hr). This area was used as the analytical section where levels of activity handled were very low and where, since April, 1952, no radioactive material had been processed.

Laboratory 5. Hood sections A and C indicated the highest radiation level of 0.1 mrep/hr. Transferable alpha contamination was observed in the ductwork from hood section A (300 d/m/sm). The average radiation level measured off the floor approached 0.05 mrep/hr. All smears yielded negative results.

Laboratory 6. The maximum radiation level observed here was measured at 0.08 mrep/hr in hood section B. All other areas were found to approach normal background and were found to be free from transferable contamination. No significant transferable contamination was observed in the duct system.

Physics Laboratory. All radiation levels observed approached a normal background of 0.02 mrep/hr. All smear tests taken yielded negative results.

Pilot Area. A final survey of this area indicated radiation levels not exceeding 0.1 mrep/hr. Transferable alpha and beta-gamma contamination is negligible.

Chemical Storage Area. The maximum radiation level (0.6 mrep/hr) was observed off the wall immediately to the left of the entrance to the area. The average radiation level off the floor was ca. 0.01 mrep/hr with a maximum of 0.2 mrep/hr.

Fenced-In Area. There was evidence of some slight overall contamination here which showed background to approach a level of 0.05 mrep/hr (ca. two times normal background). The maximum level observed on the concrete matting did not exceed 0.1 mrep/hr.

Halls, Corridors, Counter Room, Closets, and General Office Area. All radiation levels observed approached a normal background of 0.02 mrep/hr. All smear tests taken yielded negative results.

APPENDIX II

STANDARD UNITS OF MEASUREMENT

The following table has been developed for use with this report in the conversion of units of measurement from those utilized in the text to the newly adopted International System of Units (SI). Units used in the text which do not appear in this table are considered as standard under the new system.

Table II-1. Standard units of measurement

To convert from	Into SI units	Multiply by
gallons (gal)	liters (L)	3.785
inches (in)	centimeters (cm)	2.540
square inches (in^2)	square centimeters (cm^2)	6.452
feet (ft)	meters (m)	0.3048
square feet (ft^2)	square meters (m^2)	0.0929
acres (a)	hectare (ha)	0.4047
miles (mi)	kilometer (km)	1.609
millirad (mrad)	microgray (μGy)	10.0
microroentgen (μR)	coulomb per kilogram (C/kg)	2.58×10^{-10}
disintegrations per minute (dpm)	becquerel (Bq)	0.02
picocurie (pCi)	becquerel (Bq)	0.037
microcurie (μCi)	becquerel (Bq)	3.7×10^4

APPENDIX III

DESCRIPTION OF RADIATION SURVEY METERS AND SMEAR COUNTERS

RADIATION SURVEY METERS

Alpha Survey Meters

Two types of alpha survey meters are used to measure alpha radioactivity on surfaces. One type of instrument uses a ZnS(Ag) scintillator and the other uses a gas-flow proportional counter to detect the alpha radiation.

The alpha scintillation survey meter consists of a large area (100 cm^2) ZnS(Ag) detector with a photomultiplier tube in the probe which is coupled to a portable scaler/ratemeter (Fig. III-A). The ZnS(Ag) detector is covered with a 0.03-mil aluminized mylar sheet in order to make the instrument light-tight. The mylar, in turn, is covered with a grid to prevent puncturing the detector when surveying over rough surfaces. This instrument is capable of measuring alpha surface contamination levels of a few dpm/100 cm^2 but must be used in the scaler mode for this purpose. It is highly selective for densely ionizing radiation such as alpha particles, and the instrument is relatively insensitive to beta and gamma radiation.

The gas-flow proportional counter uses propane gas as the detection medium. Through front panel meter readings, it can be used to measure alpha contamination levels from a few hundred dpm/100 cm^2 to several hundred thousand dpm/100 cm^2. If individual pulses are counted, this instrument can also be used for measurements down to a few dpm/100 cm^2. The probe has a surface area of approximately 61 cm^2 and has a 0.03-mil aluminized mylar covering with a protective grid. Due to the protective grid, the active area of the probe is 50 cm^2. It is relatively insensitive to other than alpha radiation. This instrument, shown in Fig. III-B, is manufactured by the Eberline Instrument Company as their model PAC-4G meter with a probe.

Both of these instruments are calibrated at ORNL using ^{239}Pu alpha sources. While each instrument is individually calibrated, the calibration factors are typically 5 to 6 dpm/cpm.

ORNL-Photo 6705-76

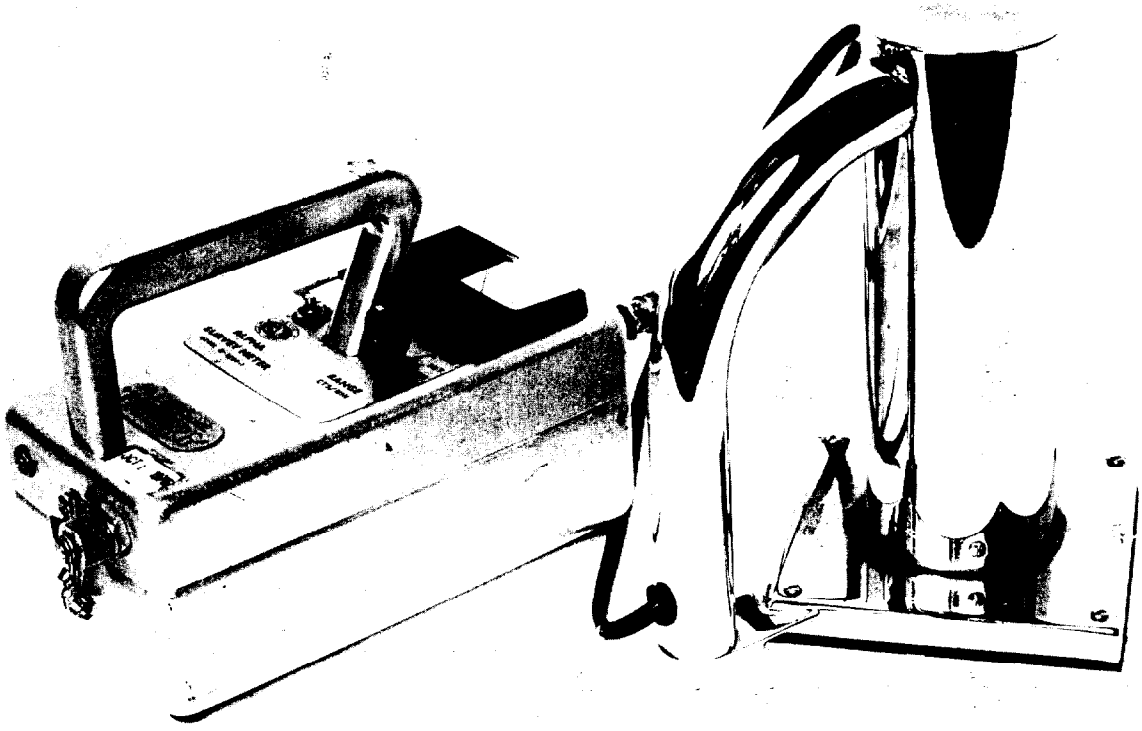

Fig. III-A. Alpha scintillation survey meter.

ORNL-Photo 6715-76

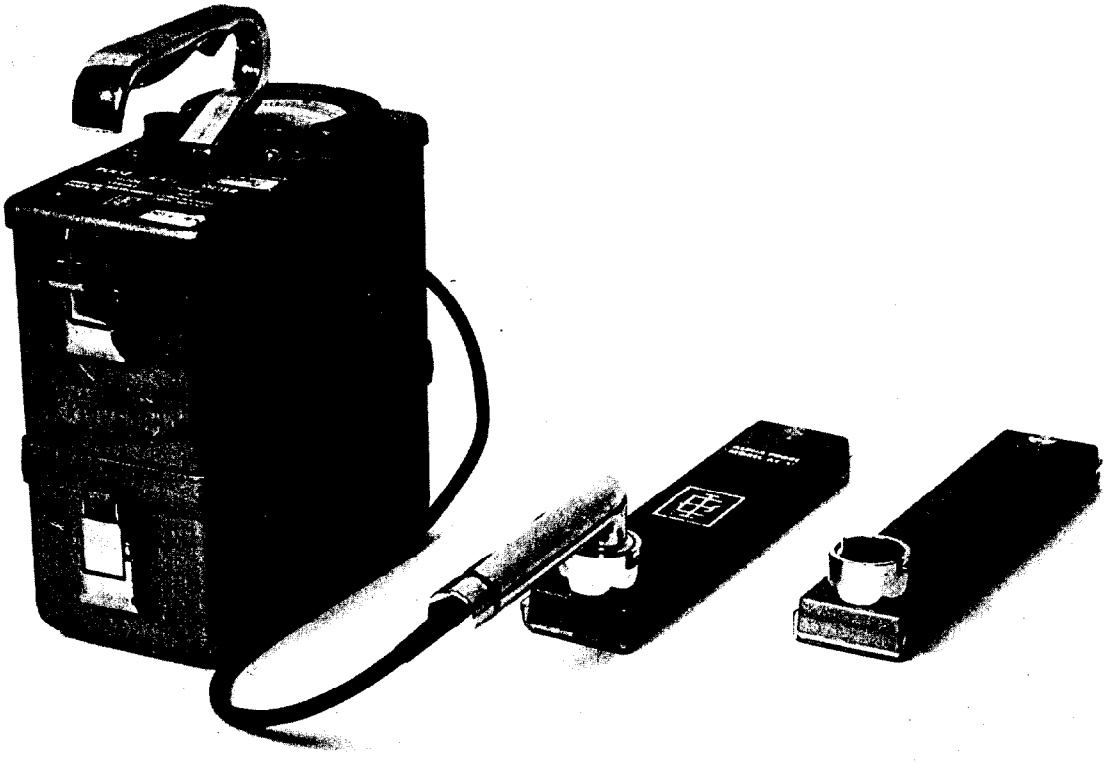

Fig. III-B. Gas-flow proportional alpha survey meter.

Beta Survey Meter

A portable Geiger-Mueller (G-M) survey meter is the primary instrument for measuring beta-gamma radioactivity. The G-M tube is a halogen-quenched stainless steel tube having a 30 mg/cm^2 wall thickness and presenting a cross-sectional area of approximately 10 cm^2. Since the G-M tube is sensitive to both beta and gamma radiation, measurements are taken in both an open-window and a closed-window configuration. Beta radiation cannot penetrate the closed window, and, thus, the beta reading can be determined by taking the difference between the open- and closed-window readings. This meter is shown in Fig. III-C.

The G-M survey meter is calibrated at ORNL for gamma radiation using a National Bureau of Standard (NBS) standard Ra source. The gamma calibration factor is typically of the order of 3,200 cpm per mR/h.

In order to assess beta-gamma surface dose rates from uranium-contaminated surfaces using this instrument, a field calibration was performed. The G-M survey meter was compared with a Victoreen Model 440 ionization chamber (Fig. III-D) and was found to produce 2,300 cpm per mrad/h with a 25% standard deviation for a wide variety of surfaces, including concrete, wood, pavement, bricks, and steel beams.

Gamma Scintillation Survey Meter

A portable survey meter using an NaI scintillation probe is used to measure low-level gamma radiation exposure. The scintillation probe is a 3.2 x 3.8-cm NaI(Tl) crystal coupled to a photomultiplier tube. This probe is connected to a Victoreen Model Thyac III ratemeter (Fig. III-E). This unit is capable of measuring radiation levels from a few μR/h to several thousand μR/h. This instrument is calibrated at ORNL with an NBS standard ^{226}Ra source. Typical calibration factors are on the order of 500 cpm per μR/h. The response of this meter is highly energy dependent. In the field, a G-M detector

ORNL-Photo 6704-76

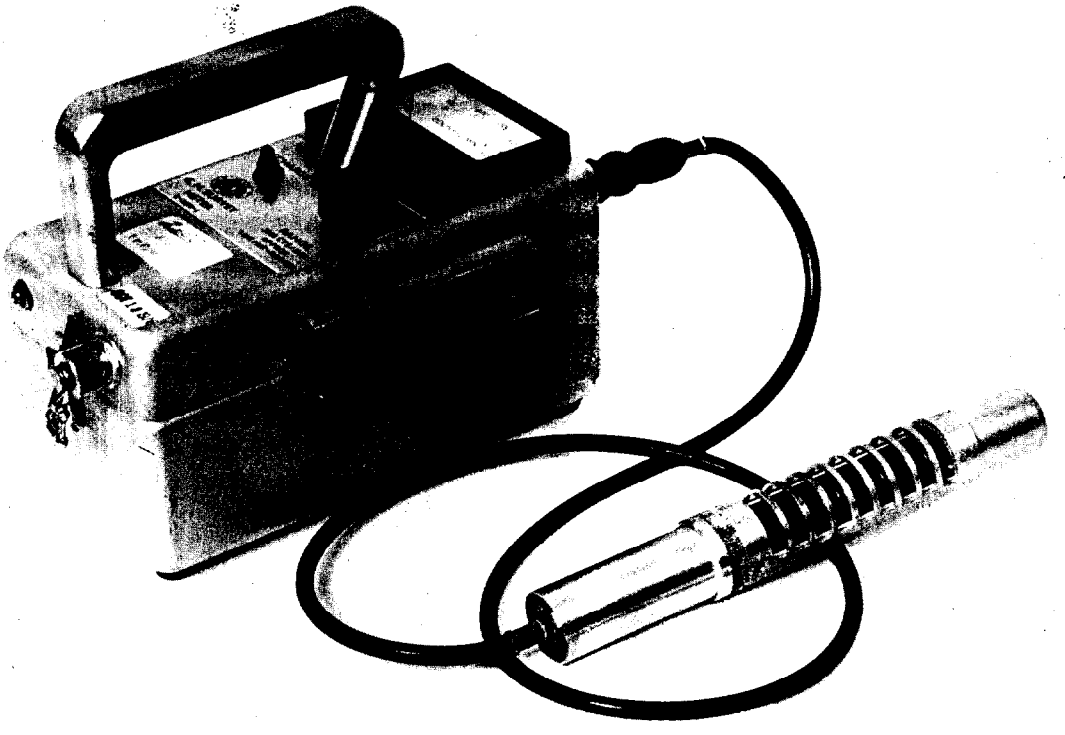

Fig. III-C. Geiger-Mueller survey meter.

ORNL-Photo 6710-76

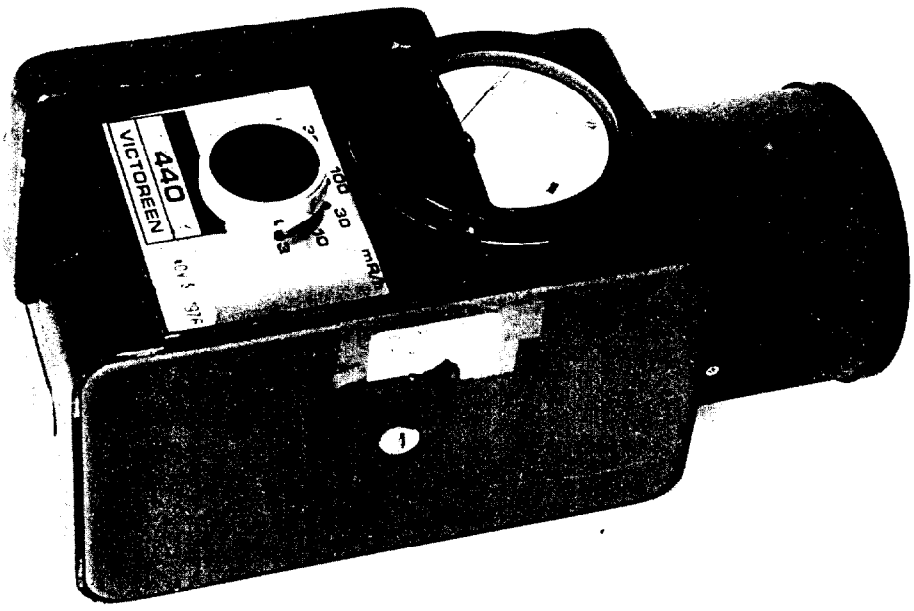

Fig. III-D. Victoreen Model 440 ionization chamber.

ORNL-Photo 6707-76

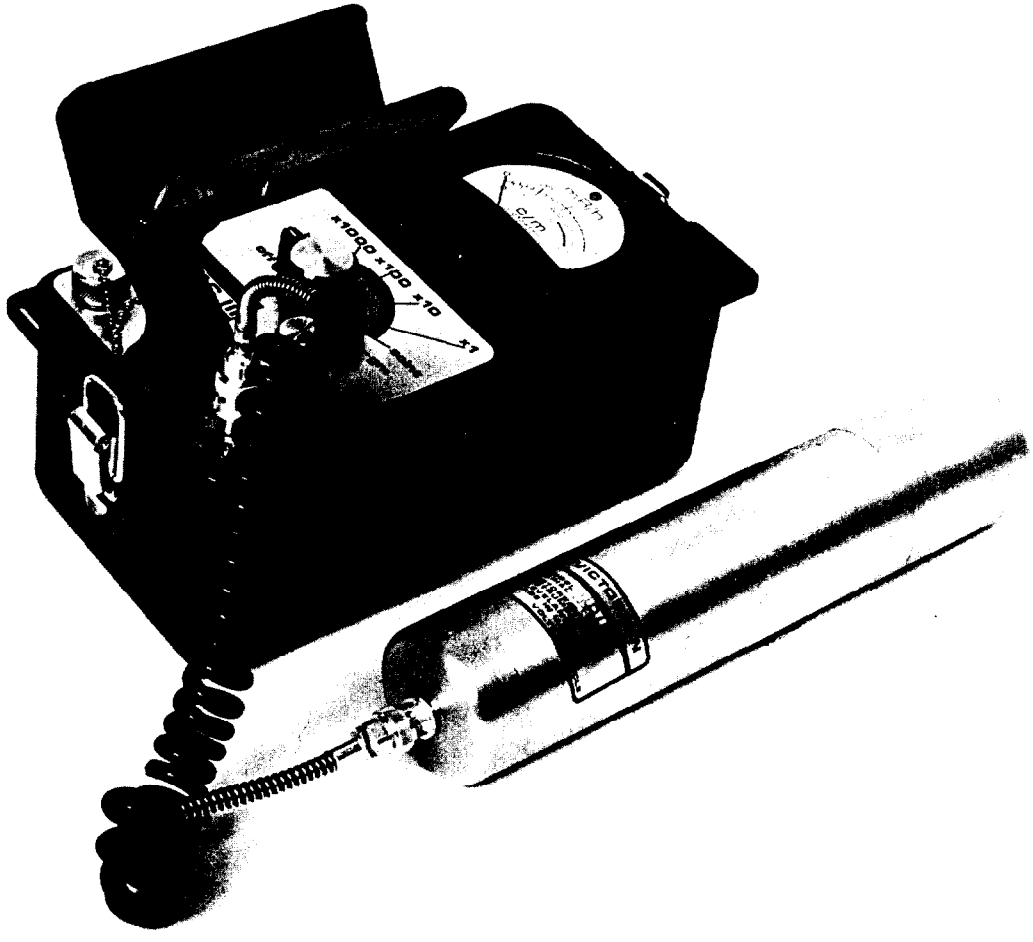

Fig. III-E. Gamma scintillation survey meter.

with a response nearly independent of photon energy is used to determine a correction factor for the scintillation meter.

SMEAR COUNTERS

Alpha Smear Counter

This detector assembly, used for the assay of alpha emitters on smear paper samples, consists of a light-tight sample holder, a Zns phosphor, and a photomultiplier tube. This detector assembly was used with electronic components housed in a portable NIM bin (Fig. III-F). The electronics package consisted of a preamplifier, an ORTEC 456 high voltage power supply, a Tennelec TC 211 linear amplifier, and a Tennelec TC 545 counter-timer.

The alpha smear counter was used in the field and calibrated daily using an alpha source with a known disintegration rate.

Beta Smear Counter

The beta smear counter consisted of a thin mica window ($\sim$2 mg/cm^2) G-M tube mounted on a sample holder and housed in a 23-cm-diam x 35-cm-high lead shield. Located under the counter window is a slotted sample holder, accessible through a hinged door on the shield. An absorber can be interposed in the slot between the sample and the counter window to determine relative beta and gamma contributions to the observed sample counting rate. The electronics for this counter were housed in a portable NIM bin and consisted of a Tennelec TC 148 preamplifier, an ORTEC 456 high-voltage power supply and a Tennelec TC 545 counter-timer.

This unit, shown in Fig. III-F, was used in the field to measure beta-gamma activity on smear papers and was calibrated daily using a gamma-ray standard of known activity.

ORNL-Photo 1070-78

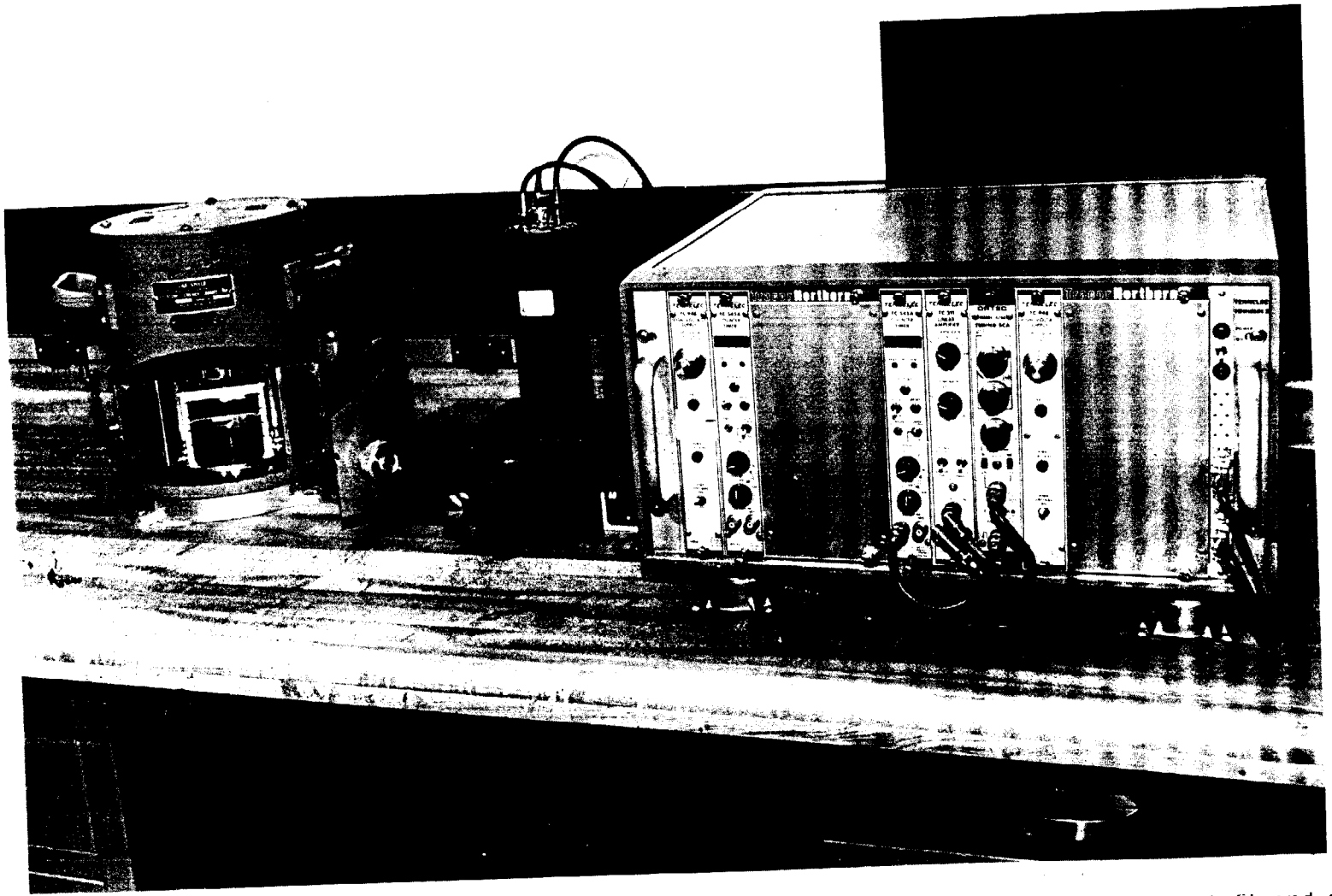

Fig. III-F. Smear counter and associated electronics. The beta counter is on the left and the alpha counter is on the right.

APPENDIX IV

SOIL ANALYTICAL PROCEDURES

ANALYSIS FOR ^{226}Ra AND ^{232}Th USING THE Ge(Li) DETECTION SYSTEM

Soil samples for ^{226}Ra and ^{232}Th analysis are dried for 24 h at 110°C and then pulverized to a particle size no greater than 500 μm in diameter (-35 mesh). Aliquots from this dried sample are transferred to 30-cm^3 polyethylene bottles (standard containers for liquid scintillation samples), weighed and stored for approximately 30 days to allow for buildup of radon and radon daughters. These bottled samples are then analyzed on the Germanium-Lithium drifted [Ge(Li)] detector system of the Off-Site Pollutant Measurements Group at ORNL.

A holder for twelve of the polyethylene bottles and a background shield have been designed for use with a 50-cm^3 Ge(Li) detector system (Figs. IV-A, IV-B). During counting of the samples, the holder is used to position ten of the sample bottles around the cylindrical surface of the detector, parallel to and symmetric about its axis, and two additional bottles across the end surface of the detector, perpendicular to and symmetric with its axis. With a 300-cm^3 sample and a graded shield developed for use with the system, it is possible to measure less than 1 pCi/g of ^{232}Th or ^{226}Ra with an error of ±10% or less. The minimal detectable concentration (MDC) for the system, considering the background of the counting system, is generally about 0.3 pCi/g.

Pulses produced by the Ge(Li) crystal are sorted by a 4096-channel analyzer (Fig. IV-C), stored on magnetic tape, and subsequently entered into a computer program, which uses a least-squares method to identify radionuclides corresponding to those gamma-ray lines found in the sample. The program, which is accessible through a remote terminal, relies on a library of radioisotopes, which contains approximately 700 isotopes and 2500 gamma-rays, and which runs continuously on the IBM-360 system at ORNL. In identifying and quantifying ^{226}Ra, six principal gamma-ray lines are analyzed. Most of these are from ^{214}Bi and correspond to 295, 352, 609, 1120, 1765, and 2204 keV. For analysis of ^{232}Th, seven gamma lines of its daughters are analyzed (239, 338, 583, 795, 911, 969, and 2615 keV).

ORNL-Photo 2172-75

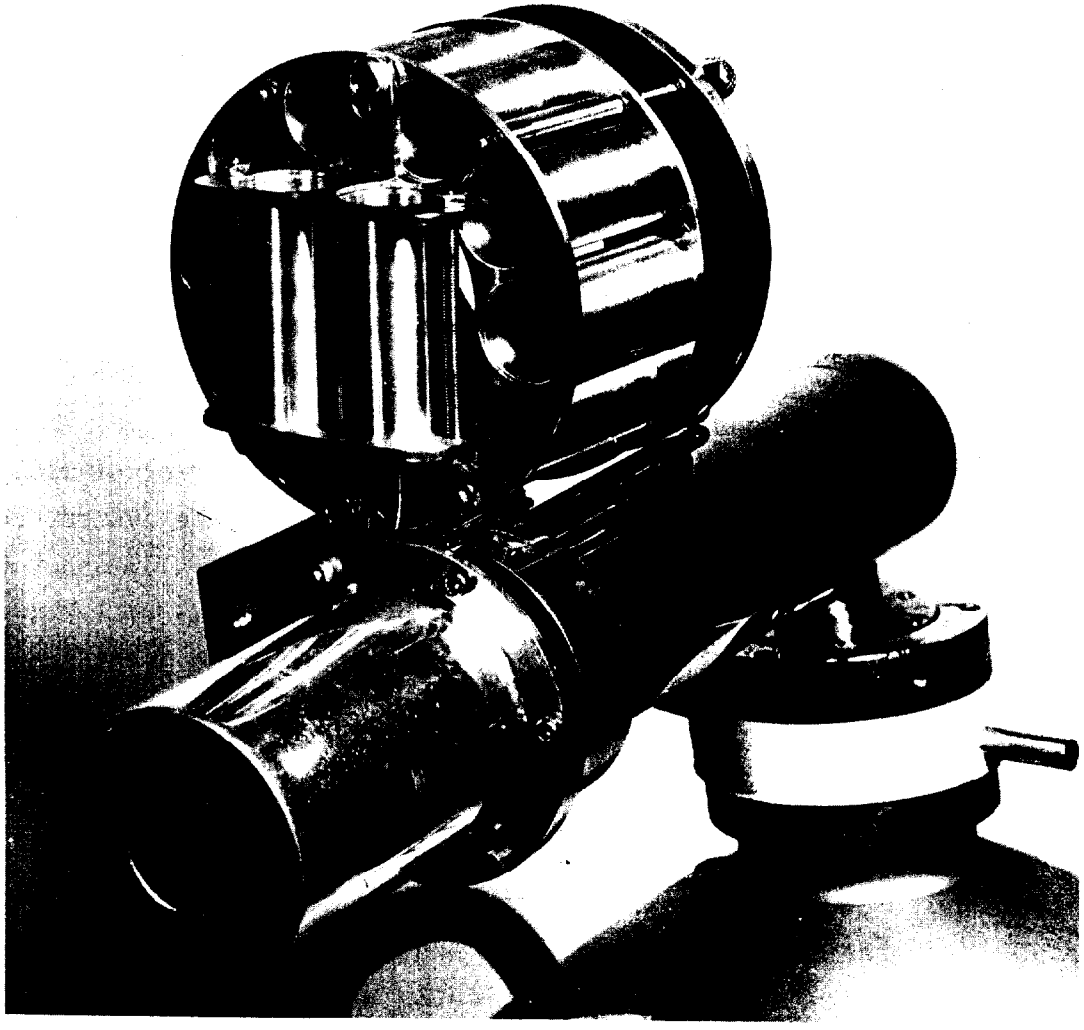

Fig. IV-A. Soil sample holder above the Ge(Li) detector system.

ORNL-Photo 2171-75

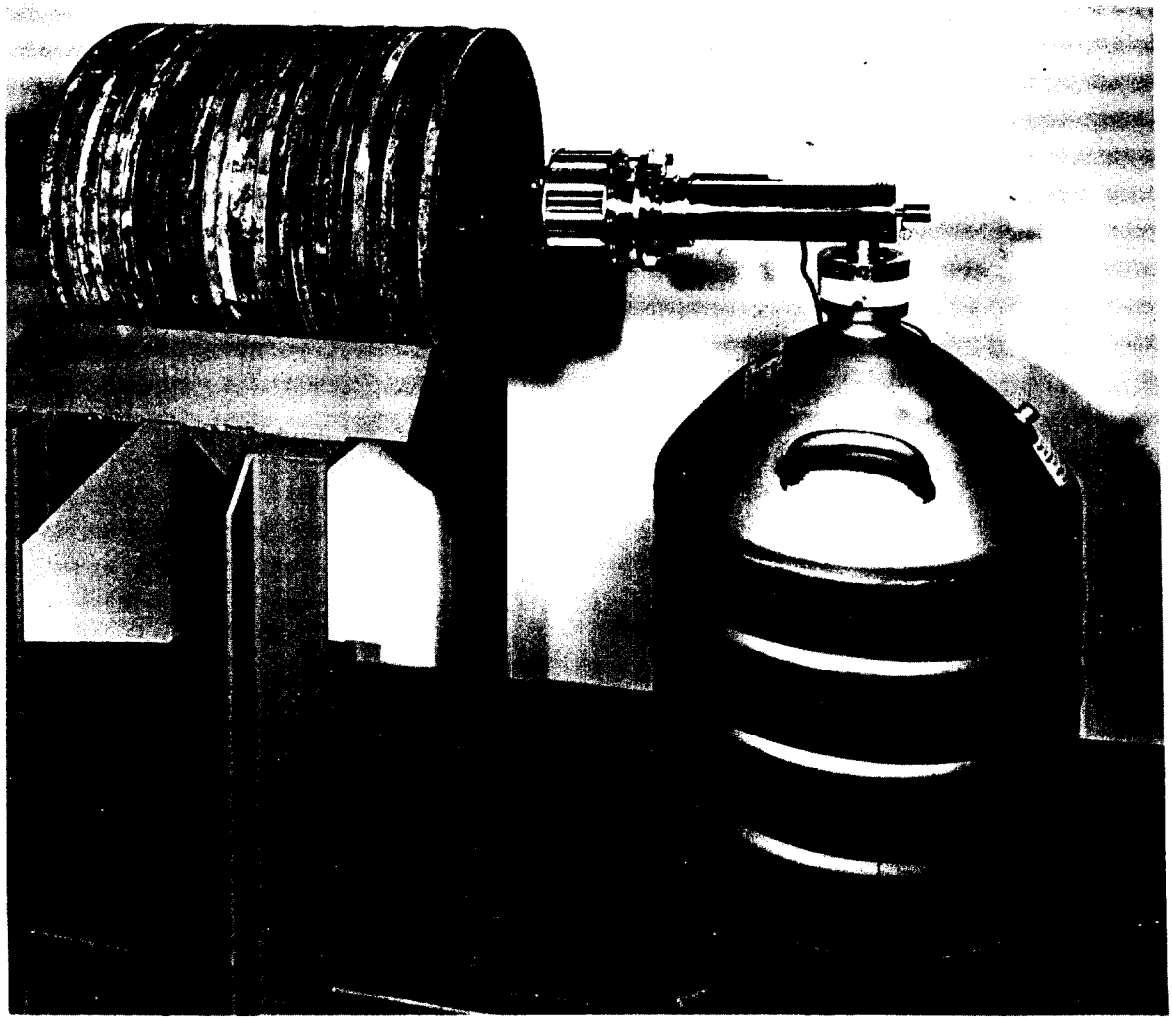

Fig. IV-B. Soil sample holder attached to Ge(Li) detector.

ORNL-Photo 6719-76

Fig. IV-C Ge(Li) detector and holder inside lead shield with associated multichannel analyzer.

NEUTRON ABSORPTION TECHNIQUE FOR ^{238}U ANALYSIS*

Following the initial soil sample drying and pulverizing, a 30 cm^3 aliquot is sent to the Analytical Chemistry Division of ORNL for ^{238}U analysis by neutron activation. The concentration of ^{235}U in the soil sample is determined by counting delayed neutrons emitted from fission products produced by neutron activation of the ^{235}U in the sample. Neutron activation of the samples are made in the pneumatic tube irradiation facility of the Oak Ridge Research Reactor. Following exposure to a thermal neutron flux of approximately 6×10^{13} $n/(cm^2 \cdot s)$, a count of the delayed-neutron activity is made using a paraffin moderator with a BF_3 tube detector assembly having a neutron counting efficiency of about 5%. The ^{235}U content of a test sample is obtained by comparing its delayed-neutron count to that obtained with a comparator sample containing a known quantity of ^{235}U. Calculations are then made utilizing the following equation:

$$^{235}U \text{ in test sample} = {}^{235}U \text{ in comparator sample} \left(\frac{\text{Net count of test sample}}{\text{Net count of comparator sample}}\right)$$

The ^{238}U concentration is then calculated assuming that 0.72% of natural uranium is ^{235}U. The precision of this method is approximately ±5% (expressed as the relative standard deviation for 2σ or 95% confidence intervals).

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*F. F. Dyer, J. F. Emery, and G. W. Leddicotte, *A Comparative Study of the Neutron Activation Analysis of Uranium by Delayed Neutron Counting*, Oak Ridge National Laboratory, ORNL-3342, October, 1962.

APPENDIX V

PERTINENT RADIOLOGICAL REGULATIONS, STANDARDS, AND GUIDELINES

A summary of applicable radiation guidelines for the former Kellex site

	Mode of exposure	Exposure conditions	Guideline value	Guideline source
1.	External gamma radiation[a]	Continuous exposure to individual in general population (whole body)	60 μR/h	Nuclear Regulatory Commission (NRC) - Standards for Protection Against Radiation (10 CFR 20.105)
2.	Surface alpha contamination[a]	^{226}Ra contamination fixed on surfaces	100 dpm/100 cm^2	NRC Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-product, Source, or Special Nuclear Material (Adapted from NRC Reg. Guide 1.86
		Removable ^{226}Ra contamination	20 dpm/100 cm^2	
3.	Surface beta contamination[a]	Removable beta-gamma emitters	1000 dpm/100 cm^2	Same as number 2
4.	Beta-gamma dose rates[a]	Average dose rate on an area no greater than 1 m^2	0.20 mrad/h	Same as number 2
		Maximum dose rate in any 100 cm^2 area	1.0 mrad/h	Same as number 2
5.	Exposure to radon[a]	Maximum permissible concentration of ^{222}Rn in air in unrestricted areas	3.0 pCi/L	NRC 10 CFR 20.103, Appendix B, Table II
6.	Radionuclides in water[a]	Maximum contaminant level for combined ^{226}Ra and ^{228}Ra in drinking water	5 pCi/L	EPA Interim Standards 40 CFR 141.15
		Maximum permissible concentration of the following radionuclides in water for unrestricted areas		NRC 10 CFR 20.103 Appendix B, Table II
		^{226}Ra	30 pCi/L	
		^{238}U	40,000 pCi/L	
		^{230}Th	2,000 pCi/L	
		^{210}Pb	100 pCi/L	
7.	Uranium concentration in soil	Average concentration of ^{238}U in the top 20 cm of soil averaged over 400 m^2 (including background)	40 pCi/g	DOE letter from William E. Mott to Department of Environmental Protection, State of New Jersey dated June 13, 1980

[a] This appendix contains a complete listing of standard.

Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source, or Special Nuclear Material

U.S. Nuclear Regulatory Commission
Division of Fuel Cycle and
Material Safety
Washington, D.C. 20555

November 1976

The instructions in this guide, in conjunction with Table V-1, specify the radioactivity and radiation exposure rate limits which should be used in accomplishing the decontamination and survey of surfaces or premises and equipment prior to abandonment or release for unrestricted use. The limits in Table V-1 do not apply to premises, equipment, or scrap containing induced radioactivity for which the radiological considerations pertinent to their use may be different. The release of such facilities or items from regulatory control will be considered on a case-by-case basis.

1. The licensee shall make a reasonable effort to eliminate residual contamination.
2. Radioactivity on equipment or surfaces shall not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the limits specified in Table V-1 prior to applying the covering. A reasonable effort must be made to minimize the contamination prior to use of any covering.
3. The radioactivity on the interior surfaces of pipes, drain lines, or ductwork shall be determined by making measurements at all traps, and other appropriate access points, provided that contamination at these locations is likely to be representative of contamination on the interior of the pipes, drain lines, or ductwork. Surfaces of premises, equipment, or scrap which are likely to be contaminated but are of such size, construction, or location as to make the surface inaccessible for purposes of measurement shall be presumed to be contaminated in excess of the limits.
4. Upon request, the Commission may authorize a licensee to relinquish possession or control of premises, equipment, or scrap having surfaces contaminated with material in excess of the limits specified. This may include, but would not be limited to, special circumstances such as razing of buildings, transfer of premises to another organization continuing work with radioactive

materials, or conversion of facilities to a long-term storage or standby status. Such request must:

a. Provide detailed, specific information describing the premises, equipment or scrap, radioactive contaminants, and the nature, extent, and degree of residual surface contamination.

b. Provide a detailed health and safety analysis which reflects that the residual amounts of material on surface areas, together with other considerations such as prospective use of the premises, equipment or scrap, are unlikely to result in an unreasonable risk to the health and safety of the public.

5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table V-1. A copy of the survey report shall be filed with the Division of Fuel Cycle and Material Safety, USNRC, Washington, D.C. 20555, and also with the Director of the Regional Office of the Office of Inspection and Enforcement, USNRC, having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report shall:

   a. Identify the premises.

   b. Show that reasonable effort has been made to eliminate residual contamination.

   c. Describe the scope of the survey and general procedures followed.

   d. State the findings of the survey in units specified in the instruction.

Following review of the report, the NRC will consider visiting the facilities to confirm the survey.

Table V-1. Acceptable surface contamination levels

Nuclides[a]	Average[b,c,f]	Maximum[b,d,f]	Removable[b,e,f]
U-nat, U-235, U-238, and associated decay products	5,000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1,000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm^2	300 dpm/100 cm^2	20 dpm/100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000 dpm/100 cm^2	3,000 dpm/100 cm^2	200 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5,000 dpm $\beta\gamma$/100 cm^2	15,000 dpm $\beta\gamma$/100 cm^2	1,000 dpm $\beta\gamma$/100 cm^2

[a] Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c] Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

[d] The maximum contamination level applies to an area of not more than 100 cm^2.

[e] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

[f] The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

NUCLEAR REGULATORY COMMISSION

EXCERPTS FROM 10 CFR 20

STANDARDS FOR PROTECTION AGAINST RADIATION

PART 20—STANDARDS FOR PROTECTION AGAINST RADIATION

AUTHORITY: Secs. 53, 63, 65, 81, 103, 104, 161, 68 Stat. 930, 933, 935, 936, 937, 948, as amended; 42 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, 2201. For the purposes of sec. 223, 68 Stat. 958, as amended; 42 U.S.C. 2273, §§ 20.401-20.408, issued under sec. 161o., 68 Stat. 950, as amended; 42 U.S.C. 2201(o). Secs. 202, 206, Pub. L. 93-438, 88 Stat. 1244, 1246 (42 U.S.C. 5842, 5846), unless otherwise noted.

SOURCE: 25 FR 10914, Nov. 17, 1960, unless otherwise noted.

NOMENCLATURE CHANGES: 40 FR 8783, Mar. 3, 1975.

GENERAL PROVISIONS

§ 20.1 Purpose.

(a) The regulations in this part establish standards for protection against radiation hazards arising out of activities under licenses issued by the Nuclear Regulatory Commission and are issued pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974.

(b) The use of radioactive material or other sources of radiation not licensed by the Commission is not subject to the regulations in this part. However, it is the purpose of the regulations in this part to control the possession, use, and transfer of licensed material by any licensee in such a manner that the total dose to an individual (including exposures to licensed and unlicensed radioactive material and to other unlicensed sources of radiation, whether in the possession of the licensee or any other person, but not including exposures to radiation from natural background sources or medical diagnosis and therapy) does not exceed the standards of radiation protection prescribed in the regulations in this part.

(c) In accordance with recommendations of the Federal Radiation Council, approved by the President, persons engaged in activities under licenses issued by the Nuclear Regulatory Commission pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974 should, in addition to complying with the requirements set forth in this part, make every reasonable effort to maintain radiation exposures, and releases of radioactive materials in effluents to unrestricted areas, as low as is reasonably achievable. The term "as low as is reasonably achievable" means as low as is reasonably achievable taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to the utilization of atomic energy in the public interest.

(Sec. 161, Pub. Law 83-703, 68 Stat. 948 (42 U.S.C. 2201); sec. 201, Pub. Law 93-430, 88 Stat. 1242 (42 U.S.C. 5841))

[25 FR 10914, Nov. 17, 1960, as amended at 40 FR 8783, Mar. 3, 1975; 40 FR 58847, Dec. 19, 1975; 44 FR 32352, June 6, 1979]

§ 20.2 Scope.

The regulations in this part apply to all persons who receive, possess, use, or transfer material licensed pursuant to the regulations in Parts 30 through 35, 40, or 70 of this chapter, including persons licensed to operate a production or utilization facility pursuant to Part 50 of this chapter.

[40 FR 8783, Mar. 3, 1975]

§ 20.3 Definitions.

(a) As used in this part:

(1) "Act" means the Atomic Energy Act of 1954 (68 Stat. 919) including any amendments thereto;

(2) "Airborne radioactive material" means any radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors, or gases;

(3) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;

(4) "Calendar quarter" means not less than 12 consecutive weeks nor more than 14 consecutive weeks. The first calendar quarter of each year shall begin in January and subsequent

calendar quarters shall be such that no day is included in more than one calendar quarter or omitted from inclusion within a calendar quarter. No licensee shall change the method observed by him of determining calendar quarters except at the beginning of a calendar year.

(5) "Commission" means the Nuclear Regulatory Commission or its duly authorized representatives;

(6) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government;

(7) "Individual" means any human being;

(8) "Licensed material" means source material, special nuclear material, or by-product material received, possessed, used, or transferred under a general or specific license issued by the Commission pursuant to the regulations in this chapter;

(9) "License" means a license issued under the regulations in Part 30, 40, or 70 of this chapter. "Licensee" means the holder of such license;

(10) "Occupational dose" includes exposure of an individual to radiation (i) in a restricted area; or (ii) in the course of employment in which the individual's duties involve exposure to radiation, provided, that "occupational dose" shall not be deemed to include any exposure of an individual to radiation for the purpose of medical diagnosis or medical therapy of such individual.

(11) "Person" means: (i) Any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Administration (except that the Administration shall be considered a person within the meaning of the regulations in this part to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission pursuant to section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244)), any State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (ii) any legal successor, representative, agent, or agency of the foregoing.

(12) "Radiation" means any or all of the following: alpha rays, beta rays, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other atomic particles; but not sound or radio waves, or visible, infrared, or ultraviolet light;

(13) "Radioactive material" includes any such material whether or not subject to licensing control by the Commission;

(14) "Restricted area" means any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include any areas used as residental quarters, although a separate room or rooms in a residential building may be set apart as a restricted area;

(15) "Source material" means: (i) Uranium or thorium, or any combination thereof, in any physical or chemical form; or (ii) ores which contain by weight one-twentieth of one percent (0.05%) or more of (*a*) uranium, (*b*) thorium or (*c*) any combination thereof. Source material does not include special nuclear material.

(16) "Special nuclear material" means: (i) Plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of section 51 of the act, determines to be special nuclear material, but does not include source material; or (ii) any material artificially enriched by any of the foregoing but does not include source material;

(17) "Unrestricted area" means any area access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

(18) "Administration" means the Energy Research and Development Administration or its duly authorized representatives.

(19) "Termination" means the end of employment with the licensee or, in the case of individuals not employed by the licensee, the end of a work assignment in the licensee's restricted areas in a given calendar quarter, without expectation or specific scheduling of reentry into the licensee's restricted areas during the remainder of that calendar quarter.

(b) Definitions of certain other words and phrases as used in this part are set forth in other sections, including:

(1) "Airborne radioactivity area" defined in § 20.203;

(2) "Radiation area" and "high radiation area" defined in § 20.202;

(3) "Personnel monitoring equipment" defined in § 20.202;

(4) "Survey" defined in § 20.201;

(5) Units of measurement of dose (rad, rem) defined in § 20.4;

(6) Units of measurement of radioactivity defined in § 20.5.

(Sec. 161, Pub. Law 83-703, 68 Stat. 948 (42 U.S.C. 2201); sec. 201, Pub. Law 93-430, 88 Stat. 1242 (42 U.S.C. 5841))

[25 FR 10914, Nov. 17, 1960, as amended at 25 FR 13953, Dec. 30, 1960; 27 FR 5905, June 22, 1962; 38 FR 22467, Aug. 21, 1973; 40 FR 8783, Mar. 3, 1975; 40 FR 42558, Sept. 15, 1975; 44 FR 32352, June 6, 1979]

§ 20.4 Units of radiation dose.

(a) "Dose," as used in this part, is the quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body. When the regulations in this part specify a dose during a period of time, the dose means the total quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body during such period of time. Several different units of dose are in current use. Definitions of units as used in this part are set forth in paragraphs (b) and (c) of this section.

(b) The rad, as used in this part, is a measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. (One millirad (mrad)=0.001 rad.)

(c) The rem, as used in this part, is a measure of the dose of any ionizing radiation to body tissues in terms of its estimated biological effect relative to a dose of one roentgen (r) of X-rays. (One millirem (mrem)=0.001 rem.) The relation of the rem to other dose units depends upon the biological effect under consideration and upon the conditions of irradiation. For the purpose of the regulations in this part, any of the following is considered to be equivalent to a dose of one rem:

(1) A dose of 1 r due to X- or gamma radiation;

(2) A dose of 1 rad due to X-, gamma, or beta radiation;

(3) A dose of 0.1 rad due to neutrons or high energy protons;

(4) A dose of 0.05 rad due to particles heavier than protons and with sufficient energy to reach the lens of the eye; If it is more convenient to measure the neutron flux, or equivalent, than to determine the neutron dose in rads, as provided in paragraph (c)(3) of this section, one rem of neutron radiation may, for purposes of the regulations in this part, be assumed to be equivalent to 14 million neutrons per square centimeter incident upon the body; or, if there exists sufficient information to estimate with reasonable accuracy the approximate distribution in energy of the neutrons, the incident number of neutrons per square centimeter equivalent to one rem may be estimated from the following table:

NEUTRON FLUX DOSE EQUIVALENTS

Neutron energy (Mev)	Number of neutrons per square centimeter equivalent to a dose of 1 rem (neutrons/cm²)	Average flux to deliver 100 millirem in 40 hours (neutrons/cm² per sec.)
Thermal	970×10^6	670
0.0001	720×10^6	500
0.005	820×10^6	570
0.02	400×10^6	280
0.1	120×10^6	80
0.5	43×10^6	30
1.0	26×10^6	18
2.5	29×10^6	20
5.0	26×10^6	18
7.5	24×10^6	17
10	24×10^6	17
10 to 30	14×10^6	10

(d) For determining exposures to X or gamma rays up to 3 Mev, the dose limits specified in §§ 20.101 to 20.104, inclusive, may be assumed to be equivalent to the "air dose". For the purpose of this part "air dose" means that the dose is measured by a properly calibrated appropriate instrument in air at or near the body surface in the region of highest dosage rate.

§ 20.5 Units of radioactivity.

(a) Radioactivity is commonly, and for purposes of the regulations in this part shall be, measured in terms of disintegrations per unit time or in curies. One curie $=3.7\times10^{10}$ disintegrations per second (dps) $=2.2\times10^{12}$ disintegrations per minute (dpm). Commonly used submultiples of the curie are the millicurie and the microcurie:

(1) One millicurie (mCi) $=0.001$ curie (Ci) $=3.7\times10^{7}$ dps.

(2) One microcurie (μCi) $=0.000001$ curie $=3.7\times10^{4}$ dps.

[25 FR 10914, Nov. 17, 1960, as amended at 38 FR 29314, Oct. 24, 1973; 39 FR 23990, June 28, 1974; 40 FR 50705, Oct. 31, 1975]

§ 20.6 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 20.7 Communications.

Except where otherwise specified in this part, all communications and reports concerning the regulations in this part should be addressed to the Executive Director for Operations, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Communications, reports, and applications may be delivered in person at the Commission's offices at 1717 H Street NW., Washington, D.C.; or at 7920 Norfolk Avenue, Bethesda, Maryland.

[40 FR 8783, Mar. 3, 1975]

Permissible Doses, Levels, and Concentrations

§ 20.101 Radiation dose standards for individuals in restricted areas.

(a) In accordance with the provisions of § 20.102(a), and except as provided in paragraph (b) of this section, no licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual in a restricted area to receive in any period of one calendar quarter from radioactive material and other sources of radiation a total occupational dose in excess of the standards specified in the following table:

Rems per Calendar Quarter	
1. Whole body; head and trunk; active blood-forming organs; lens of eyes; or gonads	1¼
2. Hands and forearms; feet and ankles	18¾
3. Skin of whole body	7½

(b) A licensee may permit an individual in a restricted area to receive a total occupational dose to the whole body greater than that permitted under paragraph (a) of this section, provided:

(1) During any calendar quarter the total occupational dose to the whole body shall not exceed 3 rems; and

(2) The dose to the whole body, when added to the accumulated occupational dose to the whole body, shall not exceed 5 (N-18) rems where "N" equals the individual's age in years at his last birthday; and

(3) The licensee has determined the individual's accumulated occupational dose to the whole body on Form NRC-4, or on a clear and legible record containing all the information required in that form; and has otherwise complied with the requirements of § 20.102. As used in paragraph (b), "Dose to the whole body" shall be deemed to include any dose to the whole body, gonads, active blood-forming organs, head and trunk, or lens of eye.

(Sec. 161, Pub. Law 83-703, 68 Stat. 948 (42 U.S.C. 2201); sec. 201, Pub. Law 93-430, 88 Stat. 1242 (42 U.S.C. 5841))

[44 FR 10914, Nov. 17, 1960, as amended at 44 FR 32352, June 6, 1979]

§ 20.102 Determination of prior dose.

(a) Each licensee shall require any individual, prior to first entry of the

individual into the licensee's restricted area during each employment or work assignment under such circumstances that the individual will receive or is likely to receive in any period of one calendar quarter an occupational dose in excess of 25 percent of the applicable standards specified in § 20.101(a) and § 20.104(a), to disclose in a written, signed statement, either: (1) That the individual had no prior occupational dose during the current calendar quarter, or (2) the nature and amount of any occupational dose which the individual may have received during that specifically identified current calendar quarter from sources of radiation possessed or controlled by other persons. Each licensee shall maintain records of such statements until the Commission authorizes their disposition.

(b) Before permitting, pursuant to § 20.101(b), any individual in a restricted area to receive an occupational radiation dose in excess of the standards specified in § 20.101(a), each licensee shall:

(1) Obtain a certificate on Form NRC-4, or on a clear and legible record containing all the information required in that form, signed by the individual showing each period of time after the individual attained the age of 18 in which the individual received an occupational dose of radiation; and

(2) Calculate on Form NRC-4 in accordance with the instructions appearing therein, or on a clear and legible record containing all the information required in that form, the previously accumulated occupational dose received by the individual and the additional dose allowed for that individual under § 20.101(b).

(c)(1) In the preparation of Form NRC-4, or a clear and legible record containing all the information required in that form, the licensee shall make a reasonable effort to obtain reports of the individual's previously accumulated occupational dose. For each period for which the licensee obtains such reports, the licensee shall use the dose shown in the report in preparing the form. In any case where a licensee is unable to obtain reports of the individual's occupational dose for a previous complete calendar quarter, it shall be assumed that the individual has received the occupational dose specified in whichever of the following columns apply:

Part of body	Column 1 Assumed exposure in rems for calendar quarters prior to Jan. 1, 1961	Column 2 Assumed exposure in rems for calendar quarters beginning on or after Jan. 1, 1961
Whole body, gonads, active blood-forming organs, head and trunk, lens of eye.	3¾	1¼

(2) The licensee shall retain and preserve records used in preparing Form NRC-4 until the Commission authorizes their disposition.

If calculation of the individual's accumulated occupational dose for all periods prior to January 1, 1961 yields a result higher than the applicable accumulated dose value for the individual as of that date, as specified in paragraph (b) of § 20.101, the excess may be disregarded.

(Sec. 161, Pub. Law 83-703, 68 Stat. 948 (42 U.S.C. 2201); sec. 201, Pub. Law 93-430, 88 Stat. 1242 (42 U.S.C. 5841))

[25 FR 10914, Nov. 17, 1960, as amended at 41 FR 18301, May 3, 1976; 44 FR 32352, June 6, 1979]

§ 20.103 Exposure of individuals to concentrations of radioactive materials in air in restricted areas.

(a)(1) No licensee shall possess, use, or transfer licensed material in such a manner as to permit any individual in a restricted area to inhale a quantity of radioactive material in any period of one calendar quarter greater than the quantity which would result from inhalation for 40 hours per week for 13 weeks at uniform concentrations of radioactive material in air specified in Appendix B, Table I, Column 1.[1][2][3] If

[1]Since the concentration specified for tritium oxide vapor assumes equal intakes by skin absorption and inhalation, the total intake permitted is twice that which would result from inhalation alone at the concentration specified for H 3 S in Appendix B,

Footnotes continued on next page

the radioactive material is of such form that intake by absorption through the skin is likely, individual exposures to radioactive material shall be controlled so that the uptake of radioactive material by any organ from either inhalation or absorption or both routes of intake [4] [5] in any calendar quarter does not exceed that which would result from inhaling such radioactive material for 40 hours per week for 13 weeks at uniform concentrations specified in Appendix B, Table I, Column 1.

(2) No licensee shall possess, use, or transfer mixtures of U-234, U-235, and U-238 in soluble form in such a manner as to permit any individual in a restricted area to inhale a quantity of such material in excess of the intake limits specified in Appendix B, Table I, Column 1 of this part. If such soluble uranium is of a form such that absorption through the skin is likely, individual exposures to such material shall be controlled so that the uptake of such material by any organ from either inhalation or absorption or both routes of intake [4] does not exceed that which would result from inhaling such material at the limits specified in Appendix B, Table I, Column 1 and footnote 4 thereto.

(3) For purposes of determining compliance with the requirements of this section the licensee shall use suitable measurements of concentrations of radioactive materials in air for detecting and evaluating airborne radioactivity in restricted areas and in addition, as appropriate, shall use measurements of radioactivity in the body, measurements of radioactivity excreted from the body, or any combination of such measurements as may be necessary for timely detection and assessment of individual intakes of radioactivity by exposed individuals. It is assumed that an individual inhales radioactive material at the airborne concentration in which he is present unless he uses respiratory protective equipment pursuant to paragraph (c) of this section. When assessment of a particular individual's intake of radioactive material is necessary, intakes less than those which would result from inhalation for 2 hours in any one day or for 10 hours in any one week at uniform concentrations specified in Appendix B, Table I, Column 1 need not be included in such assessment, provided that for any assessment in excess of these amounts the entire amount is included.

(b)(1) The licensee shall, as a precautionary procedure, use process or other engineering controls, to the extent practicable, to limit concentrations of radioactive materials in air to levels below those which delimit an airborne radioactivity area as defined in § 20.203(d)(1)(ii).

(2) When it is impracticable to apply process or other engineering controls to limit concentrations of radioactive material in air below those defined in § 20.203(d)(1)(ii), other precautionary procedures, such as increased surveillance, limitation of working times, or

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Footnotes continued from previous page

Table I, Column 1 for 40 hours per week for 13 weeks.

[2] For radon-222, the limiting quantity is that inhaled in a period of one calendar year. For radioactive materials designated "Sub" in the "Isotope" column of the table, the concentration value specified is based upon exposure to the material as an external radiation source. Individual exposures to these materials may be accounted for as part of the limitation on individual dose in § 20.101. These nuclides shall be subject to the precautionary procedures required by § 20.103(b)(1).

[3] Multiply the concentration values specified in Appendix B, Table I, column 1, by 6.3×10^{5} ml to obtain the quarterly quantity limit. Multiply the concentration value specified in Appendix B, Table I, column 1, by 2.5×10^{9} ml to obtain the annual quantity limit for Rn-222.

[4] Significant intake by ingestion or injection is presumed to occur only as a result of circumstances such as accident, inadvertence, poor procedure, or similar special conditions. Such intakes must be evaluated and accounted for by techniques and procedures as may be appropriate to the circumstances of the occurrence. Exposures so evaluated shall be included in determining whether the limitation on individual exposures in § 20.103(a)(1) has been exceeded.

[5] Regulatory guidance on assessment of individual intakes of radioactive material is given in Regulatory Guide 8.9, "Acceptable Concepts, Models, Equations and Assumptions for a Bioassay Program," single copies of which are available from the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, upon written request.

provision of respiratory protective equipment, shall be used to maintain intake of radioactive material by any individual within any period of seven consecutive days as far below that intake of radioactive material which would result from inhalation of such material for 40 hours at the uniform concentrations specified in Appendix B, Table 1, Column 1 as is reasonably achievable. Whenever the intake of radioactive material by any individual exceeds this 40-hour control measure, the licensee shall make such evaluations and take such actions as are necessary to assure against recurrence. The licensee shall maintain records of such occurrences, evaluations, and actions taken in a clear and readily identifiable form suitable for summary review and evaluation.

(c) When respiratory protective equipment is used to limit the inhalation of airborne radioactive material pursuant to paragraph (b)(2) of this section, the licensee may make allowance for such use in estimating exposures of individuals to such materials provided that such equipment is used as stipulated in Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection."[6]

(d) Notwithstanding the provisions of paragraphs (b) and (c) of this section, the Commission may impose further restrictions:

(1) On the extent to which a licensee may make allowance for use of respirators in lieu of provision of process, containment, ventilation, or other engineering controls, if application of such controls is found to be practicable; and

(2) As might be necessary to assure that the respiratory protective program of the licensee is adequate in limiting exposures of personnel to airborne radioactive materials.

(e) The licensee shall notify, in writing, the Director of the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office listed in Appendix D at least 30 days before the date that respiratory protective equipment is first used under the provisions of this section.

(f) A licensee who was authorized to make allowance for use of respiratory protective equipment prior to December 29, 1976 shall bring his respiratory protective program into conformance with the requirements of paragraph (c) of this section within one year of that date, and is exempt from the requirement of paragraph (e) of this section.

(Sec. 161, Pub. L. 83-703, 68 Stat. 948 (42 U.S.C. 2201); sec. 201, Pub. L. 93-438, 88 Stat. 1242 (42 U.S.C. 5841))

[41 FR 52301, Nov. 29, 1976, as amended at 43 FR 29270, July 7, 1978]

§ 20.104 Exposure of minors.

(a) No licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual within a restricted area who is under 18 years of age, to receive in any period of one calendar quarter from radioactive material and other sources of radiation in the licensee's possession a dose in excess of 10 percent of the limits specified in the table in paragraph (a) of § 20.101.

(b) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual within a restricted area, who is under 18 years of age to be exposed to airborne radioactive material possessed by the licensee in an average concentration in excess of the limits specified in Appendix B, Table II of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than a week.

(c) The provisions of §§ 20.103(b)(2) and 20.103(c) shall apply to exposures subject to paragraph (b) of this section except that the references in §§ 20.103(b)(2) and 20.103(c) to Appendix B, Table I, Column 1 shall be deemed to be references to Appendix B, Table II, Column 1.

[25 FR 10914, Nov. 17, 1960, as amended at 41 FR 52302, Nov. 29, 1976]

[6] This incorporation by reference provision was approved by the Director of the Federal Register on October 19, 1976. Single copies of Regulatory Guide 8.15 are available from the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, upon written request.

§ 20.105 Permissible levels of radiation in unrestricted areas.

(a) There may be included in any application for a license or for amendment of a license proposed limits upon levels of radiation in unrestricted areas resulting from the applicant's possession or use of radioactive material and other sources of radiation. Such applications should include information as to anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved. The Commission will approve the proposed limits if the applicant demonstrates that the proposed limits are not likely to cause any individual to receive a dose to the whole body in any period of one calendar year in excess of 0.5 rem.

(b) Except as authorized by the Commission pursuant to paragraph (a) of this section, no licensee shall possess, use or transfer licensed material in such a manner as to create in any unrestricted area from radioactive material and other sources of radiation in his possession:

(1) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of two millirems in any one hour, or

(2) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of 100 millirems in any seven consecutive days.

§ 20.106 Radioactivity in effluents to unrestricted areas.

(a) A licensee shall not possess, use, or transfer licensed material so as to release to an unrestricted area radioactive material in concentrations which exceed the limits specified in Appendix "B", Table II of this part, except as authorized pursuant to § 20.302 or paragraph (b) of this section. For purposes of this section concentrations may be averaged over a period not greater than one year.

(b) An application for a license or amendment may include proposed limits higher than those specified in paragraph (a) of this section. The Commission will approve the proposed limits if the applicant demonstrates:

(1) That the applicant has made a reasonable effort to minimize the radioactivity contained in effluents to unrestricted areas; and

(2) That it is not likely that radioactive material discharged in the effluent would result in the exposure of an individual to concentrations of radioactive material in air or water exceeding the limits specified in Appendix "B", Table II of this part.

(c) An application for higher limits pursuant to paragraph (b) of this section shall include information demonstrating that the applicant has made a reasonable effort to minimize the radioactivity discharged in effluents to unrestricted areas, and shall include, as pertinent:

(1) Information as to flow rates, total volume of effluent, peak concentration of each radionuclide in the effluent, and concentration of each radionuclide in the effluent averaged over a period of one year at the point where the effluent leaves a stack, tube, pipe, or similar conduit;

(2) A description of the properties of the effluents, including:

(i) Chemical composition;

(ii) Physical characteristics, including suspended solids content in liquid effluents, and nature of gas or aerosol for air effluents;

(iii) The hydrogen ion concentrations (p^H) of liquid effluents; and

(iv) The size range of particulates in effluents released into air.

(3) A description of the anticipated human occupancy in the unrestricted area where the highest concentration of radioactive material from the effluent is expected, and, in the case of a river or stream, a description of water uses downstream from the point of release of the effluent.

(4) Information as to the highest concentration of each radionuclide in an unrestricted area, including anticipated concentrations averaged over a period of one year:

(i) In air at any point of human occupancy; or

(ii) In water at points of use downstream from the point of release of the effluent.

(5) The background concentration of radionuclides in the receiving river or

stream prior to the release of liquid effluent.

(6) A description of the environmental monitoring equipment, including sensitivity of the system, and procedures and calculations to determine concentrations of radionuclides in the unrestricted area and possible reconcentrations of radionuclides.

(7) A description of the waste treatment facilities and procedures used to reduce the concentration of radionuclides in effluents prior to their release.

(d) For the purposes of this section the concentration limits in Appendix "B", Table II of this part shall apply at the boundary of the restricted area. The concentration of radioactive material discharged through a stack, pipe or similar conduit may be determined with respect to the point where the material leaves the conduit. If the conduit discharges within the restricted area, the concentration at the boundary may be determined by applying appropriate factors for dilution, dispersion, or decay between the point of discharge and the boundary.

(e) In addition to limiting concentrations in effluent streams, the Commission may limit quantities of radioactive materials released in air or water during a specified period of time if it appears that the daily intake of radioactive material from air, water, or food by a suitable sample of an exposed population group, averaged over a period not exceeding one year, would otherwise exceed the daily intake resulting from continuous exposure to air or water containing one-third the concentration of radioactive materials specified in Appendix "B", Table II of this part.

(f) The provisions of this section do not apply to disposal of radioactive material into sanitary sewerage systems, which is governed by § 20.303.

[29 FR 14434, Oct. 21, 1964]

§ 20.107 Medical diagnosis and therapy.

Nothing in the regulations in this part shall be interpreted as limiting the intentional exposure of patients to radiation for the purpose of medical diagnosis or medical therapy.

§ 20.108 Orders requiring furnishing of bio-assay services.

Where necessary or desirable in order to aid in determining the extent of an individual's exposure to concentrations of radioactive material, the Commission may incorporate appropriate provisions in any license, directing the licensee to make available to the individual appropriate bio-assay services and to furnish a copy of the reports of such services to the Commission.

Precautionary Procedures

§ 20.201 Surveys.

(a) As used in the regulations in this part, "survey" means an evaluation of the radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and equipment, and measurements of levels of radiation or concentrations of radioactive material present.

(b) Each licensee shall make or cause to be made such surveys as may be necessary for him to comply with the regulations in this part.

§ 20.202 Personnel monitoring.

(a) Each licensee shall supply appropriate personnel monitoring equipment to, and shall require the use of such equipment by:

(1) Each individual who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in any calendar quarter in excess of 25 percent of the applicable value specified in paragraph (a) of § 20.101.

(2) Each individual under 18 years of age who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in any calendar quarter in excess of 5 percent of the applicable value specified in paragraph (a) of § 20.101.

(3) Each individual who enters a high radiation area.

(b) As used in this part,

(1) "Personnel monitoring equipment" means devices designed to be worn or carried by an individual for

Energy Reorganization Act of 1974, or any rule, regulation, or order issued thereunder, or any term, condition, or limitation of any license issued thereunder, or for any violation for which a license may be revoked under section 186 of the Act. Any person who willfully violates any provision of the Act or any regulation or order issued thereunder may be guilty of a crime and, upon conviction, may be punished by fine or imprisonment or both, as provided by law.

(Sec. 201, Pub. L. 93-438, 88 Stat. 1242 (42 U.S.C. 5841))

[40 FR 8784, Mar. 3, 1975, as amended at 42 FR 25721, May 19, 1977]

NOTE.—The reporting and record keeping requirements contained in this part have been approved by the General Accounting Office under B-180225 (R0043), (R0044), and (R0084).

APPENDIX A—[RESERVED]

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)
Actinium (89)	Ac 227	S	2×10^{-12}	6×10^{-8}	8×10^{-14}	2×10^{-9}
		I	3×10^{-11}	9×10^{-7}	9×10^{-13}	3×10^{-8}
	Ac 228	S	8×10^{-8}	3×10^{-6}	3×10^{-9}	9×10^{-8}
		I	2×10^{-9}	3×10^{-7}	6×10^{-10}	9×10^{-9}
Americium (95)	Am 241	S	6×10^{-13}	1×10^{-8}	2×10^{-13}	4×10^{-9}
		I	1×10^{-10}	8×10^{-8}	4×10^{-12}	3×10^{-8}
	Am 242m	S	6×10^{-12}	1×10^{-8}	2×10^{-12}	4×10^{-9}
		I	3×10^{-10}	3×10^{-7}	9×10^{-12}	9×10^{-8}
	Am 242	S	4×10^{-8}	4×10^{-7}	1×10^{-8}	1×10^{-7}
		I	5×10^{-8}	4×10^{-7}	2×10^{-8}	1×10^{-7}
	Am 243	S	6×10^{-13}	1×10^{-8}	2×10^{-13}	4×10^{-9}
		I	1×10^{-10}	8×10^{-8}	4×10^{-12}	3×10^{-8}
	Am 244	S	4×10^{-6}	1×10^{-4}	1×10^{-7}	5×10^{-7}
		I	2×10^{-5}	1×10^{-4}	8×10^{-7}	5×10^{-7}
Antimony	Sb 122	S	2×10^{-7}	8×10^{-8}	6×10^{-9}	3×10^{-8}
		I	1×10^{-7}	8×10^{-8}	5×10^{-9}	3×10^{-8}
	Sb 124	S	2×10^{-7}	7×10^{-8}	5×10^{-9}	2×10^{-8}
		I	2×10^{-6}	7×10^{-8}	7×10^{-10}	2×10^{-8}
	Sb 125	S	5×10^{-7}	3×10^{-7}	2×10^{-8}	1×10^{-7}
		I	3×10^{-6}	3×10^{-7}	9×10^{-10}	1×10^{-7}
Argon (18)	A 37	Sub [2]	6×10^{-3}	.....	1×10^{-4}	.....
	A 41	Sub	2×10^{-6}	.....	4×10^{-8}	.....
Arsenic (33)	As 73	S	2×10^{-6}	1×10^{-7}	7×10^{-8}	5×10^{-8}
		I	4×10^{-7}	1×10^{-7}	1×10^{-8}	5×10^{-8}
	As 74	S	3×10^{-7}	2×10^{-7}	1×10^{-8}	5×10^{-8}
		I	1×10^{-7}	2×10^{-7}	4×10^{-9}	5×10^{-8}
	As 76	S	1×10^{-7}	6×10^{-8}	4×10^{-9}	2×10^{-8}
		I	1×10^{-7}	6×10^{-8}	3×10^{-9}	2×10^{-8}
	As 77	S	5×10^{-7}	2×10^{-7}	2×10^{-8}	8×10^{-8}
		I	4×10^{-7}	2×10^{-7}	1×10^{-8}	8×10^{-8}
Astatine (85)	At 211	S	7×10^{-8}	5×10^{-8}	2×10^{-10}	2×10^{-8}
		I	3×10^{-8}	2×10^{-7}	1×10^{-9}	7×10^{-8}
Barium (56)	Ba 131	S	1×10^{-6}	5×10^{-7}	4×10^{-8}	2×10^{-7}
		I	4×10^{-7}	5×10^{-7}	1×10^{-8}	2×10^{-7}
	Ba 140	S	1×10^{-7}	6×10^{-8}	4×10^{-9}	3×10^{-8}
		I	4×10^{-8}	7×10^{-8}	1×10^{-9}	2×10^{-8}
Berkelium (97)	Bk 249	S	9×10^{-10}	2×10^{-7}	3×10^{-11}	6×10^{-8}
		I	1×10^{-7}	2×10^{-7}	4×10^{-9}	6×10^{-8}
	Bk 250	S	1×10^{-7}	6×10^{-8}	5×10^{-9}	2×10^{-8}
		I	1×10^{-6}	6×10^{-8}	4×10^{-8}	2×10^{-8}
Beryllium (4)	Be 7	S	6×10^{-6}	5×10^{-8}	2×10^{-7}	2×10^{-8}
		I	1×10^{-6}	5×10^{-8}	4×10^{-8}	2×10^{-8}

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See notes at end of appendix]

Element (atomic number)	Isotope[1]		Table I Col. 1 Air (μCi/ml)	Table I Col. 2 Water (μCi/ml)	Table II Col. 1 Air (μCi/ml)	Table II Col. 2 Water (μCi/ml)
Bismuth (83)	Bi 206	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	1×10^{-7}	1×10^{-3}	5×10^{-9}	4×10^{-5}
	Bi 207	S	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
		I	1×10^{-8}	2×10^{-3}	5×10^{-10}	6×10^{-5}
	Bi 210	S	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
		I	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Bi 212	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-4}
Bromine (35)	Br 82	S	1×10^{-6}	8×10^{-3}	4×10^{-8}	3×10^{-4}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Cadmium (48)	Cd 109	S	5×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
		I	7×10^{-8}	5×10^{-3}	3×10^{-9}	2×10^{-4}
	Cd 115m	S	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
	Cd 115	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Calcium (20)	Ca 45	S	3×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Ca 47	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
Californium (98)	Cf 249	S	2×10^{-12}	1×10^{-4}	5×10^{-14}	4×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cf 250	S	5×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 251	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 252	S	6×10^{-12}	2×10^{-4}	2×10^{-13}	7×10^{-6}
		I	3×10^{-11}	2×10^{-4}	1×10^{-12}	7×10^{-6}
	Cf 253	S	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
		I	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
	Cf 254	S	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
		I	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
Carbon (6)	C 14	S	4×10^{-6}	2×10^{-3}	1×10^{-7}	8×10^{-4}
	(CO_2)	Sub	5×10^{-5}	.....	1×10^{-6}	.....
Cerium (58)	Ce 141	S	4×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	3×10^{-3}	5×10^{-9}	9×10^{-5}
	Ce 143	S	3×10^{-7}	1×10^{-3}	9×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	Ce 144	S	1×10^{-8}	3×10^{-4}	3×10^{-10}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Cesium (55)	Cs 131	S	1×10^{-5}	7×10^{-3}	4×10^{-7}	2×10^{-3}
		I	3×10^{-6}	3×10^{-3}	1×10^{-7}	9×10^{-4}
	Cs 134m	S	4×10^{-6}	2×10^{-1}	1×10^{-6}	6×10^{-3}
		I	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Cs 134	S	4×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-6}	1×10^{-3}	4×10^{-10}	4×10^{-5}
	Cs 135	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	9×10^{-8}	7×10^{-3}	3×10^{-9}	2×10^{-4}
	Cs 136	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
	Cs 137	S	6×10^{-8}	4×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-6}	1×10^{-3}	5×10^{-10}	4×10^{-5}
Chlorine (17)	Cl 36	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
		I	2×10^{-6}	2×10^{-3}	8×10^{-10}	6×10^{-5}
	Cl 38	S	3×10^{-6}	1×10^{-3}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-3}	7×10^{-8}	4×10^{-4}
Chromium (24)	Cr 51	S	1×10^{-5}	5×10^{-3}	4×10^{-7}	2×10^{-3}
		I	2×10^{-6}	5×10^{-3}	8×10^{-8}	2×10^{-3}

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)
Cobalt (27)	Co 57	S	3×10^{-6}	2×10^{-3}	1×10^{-7}	5×10^{-4}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-4}
	Co 58m	S	2×10^{-5}	8×10^{-3}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	6×10^{-3}	3×10^{-7}	2×10^{-3}
	Co 58	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-8}	3×10^{-3}	2×10^{-8}	9×10^{-5}
	Co 60	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	9×10^{-8}	1×10^{-3}	3×10^{-10}	3×10^{-5}
Copper (29)	Cu 64	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Curium (96)	Cm 242	S	1×10^{-10}	7×10^{-4}	4×10^{-12}	2×10^{-5}
		I	2×10^{-10}	7×10^{-4}	6×10^{-12}	2×10^{-5}
	Cm 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	5×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cm 244	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cm 245	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 246	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 247	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	6×10^{-4}	4×10^{-12}	2×10^{-5}
	Cm 248	S	6×10^{-13}	1×10^{-5}	2×10^{-14}	4×10^{-7}
		I	1×10^{-11}	4×10^{-5}	4×10^{-13}	1×10^{-6}
	Cm 249	S	1×10^{-5}	6×10^{-3}	4×10^{-7}	2×10^{-3}
		I	1×10^{-5}	6×10^{-3}	4×10^{-7}	2×10^{-3}
Dysprosium (66)	Dy 165	S	3×10^{-6}	1×10^{-3}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-3}	7×10^{-8}	4×10^{-4}
	Dy 166	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Einsteinium (99)	Es 253	S	8×10^{-10}	7×10^{-4}	3×10^{-11}	2×10^{-5}
		I	6×10^{-10}	7×10^{-4}	2×10^{-11}	2×10^{-5}
	Es 254m	S	5×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
		I	6×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
	Es 254	S	2×10^{-11}	4×10^{-4}	6×10^{-13}	1×10^{-5}
		I	1×10^{-10}	4×10^{-4}	4×10^{-12}	1×10^{-5}
	Es 255	S	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	4×10^{-10}	8×10^{-4}	1×10^{-11}	3×10^{-5}
Erbium (68)	Er 169	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	Er 171	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Europium (63)	Eu 152	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	(T/2=9.2 hrs)	I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Eu 152	S	1×10^{-6}	2×10^{-3}	4×10^{-10}	8×10^{-5}
	(T/2=13 yrs)	I	2×10^{-6}	2×10^{-3}	6×10^{-10}	8×10^{-5}
	Eu 154	S	4×10^{-9}	6×10^{-4}	1×10^{-10}	2×10^{-5}
		I	7×10^{-9}	6×10^{-4}	2×10^{-10}	2×10^{-5}
	Eu 155	S	9×10^{-9}	6×10^{-3}	3×10^{-9}	2×10^{-4}
		I	7×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
Fermium (100)	Fm 254	S	6×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
		I	7×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Fm 255	S	2×10^{-8}	1×10^{-3}	6×10^{-10}	3×10^{-5}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	3×10^{-5}
	Fm 256	S	3×10^{-9}	3×10^{-5}	1×10^{-10}	9×10^{-7}
		I	2×10^{-9}	3×10^{-5}	6×10^{-11}	9×10^{-7}
Fluorine (9)	F 18	S	5×10^{-6}	2×10^{-3}	2×10^{-7}	8×10^{-4}
		I	3×10^{-6}	1×10^{-3}	9×10^{-8}	5×10^{-4}

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)
Gadolinium (64)	Gd 153	S	2×10^{-7}	6×10^{-3}	8×10^{-9}	2×10^{-4}
		I	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Gd 159	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Gallium (31)	Ga 72	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Germanium (32)	Ge 71	S	1×10^{-6}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
Gold (79)	Au 196	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
	Au 198	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Au 199	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	8×10^{-7}	4×10^{-3}	3×10^{-8}	2×10^{-4}
Hafnium (72)	Hf 181	S	4×10^{-6}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	7×10^{-8}	2×10^{-3}	3×10^{-9}	7×10^{-5}
Holmium (67)	Ho 166	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Hydrogen (1)	H3	S	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		I	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		Sub	2×10^{-5}	.....	4×10^{-5}	
Indium (49)	In 113m	S	8×10^{-6}	4×10^{-3}	3×10^{-7}	1×10^{-3}
		I	7×10^{-6}	4×10^{-3}	2×10^{-7}	1×10^{-3}
	In 114m	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	2×10^{-6}	5×10^{-4}	7×10^{-10}	2×10^{-5}
	In 115m	S	2×10^{-6}	1×10^{-3}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-3}	6×10^{-8}	4×10^{-4}
	In 115	S	2×10^{-7}	3×10^{-3}	9×10^{-9}	9×10^{-5}
		I	3×10^{-6}	3×10^{-3}	1×10^{-8}	9×10^{-5}
Iodine (53)	I 125	S	5×10^{-9}	4×10^{-5}	8×10^{-11}	2×10^{-7}
		I	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
	I 126	S	8×10^{-9}	5×10^{-5}	9×10^{-11}	3×10^{-7}
		I	3×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	I 129	S	2×10^{-8}	1×10^{-4}	2×10^{-11}	6×10^{-8}
		I	7×10^{-6}	6×10^{-3}	2×10^{-8}	2×10^{-4}
	I 131	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	I 132	S	2×10^{-7}	2×10^{-3}	3×10^{-9}	8×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	I 133	S	3×10^{-8}	2×10^{-4}	4×10^{-10}	1×10^{-6}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I 134	S	5×10^{-7}	4×10^{-3}	6×10^{-9}	2×10^{-5}
		I	3×10^{-6}	2×10^{-3}	1×10^{-7}	6×10^{-4}
	I 135	S	1×10^{-7}	7×10^{-4}	1×10^{-9}	4×10^{-6}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Iridium (77)	Ir 190	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ir 192	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-5}
		I	3×10^{-8}	1×10^{-3}	9×10^{-10}	4×10^{-5}
	Ir 194	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
Iron (26)	Fe 55	S	9×10^{-7}	2×10^{-2}	3×10^{-8}	8×10^{-4}
		I	1×10^{-6}	7×10^{-2}	3×10^{-8}	2×10^{-3}
	Fe 59	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	5×10^{-5}

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See notes at end of appendix]

Element (atomic number)	Isotope[1]		Table I		Table II	
			Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)
Palladium (46)	Pd 103	S	1×10^{-6}	1×10^{-3}	5×10^{-8}	3×10^{-4}
		I	7×10^{-7}	8×10^{-3}	3×10^{-8}	3×10^{-4}
	Pd 109	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Phosphorus (15)	P 32	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	8×10^{-8}	7×10^{-4}	3×10^{-9}	2×10^{-5}
Platinum (78)	Pt 191	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Pt 193m	S	7×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Pt 193	S	1×10^{-6}	3×10^{-3}	4×10^{-8}	9×10^{-5}
		I	3×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Pt 197m	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
	Pt 197	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Plutonium (94)	Pu 238	S	2×10^{-13}	1×10^{-6}	7×10^{-14}	5×10^{-9}
		I	3×10^{-11}	8×10^{-6}	1×10^{-12}	3×10^{-8}
	Pu 239	S	2×10^{-13}	1×10^{-6}	6×10^{-14}	5×10^{-9}
		I	4×10^{-11}	8×10^{-6}	1×10^{-12}	3×10^{-8}
	Pu 240	S	2×10^{-13}	1×10^{-6}	6×10^{-14}	5×10^{-9}
		I	4×10^{-11}	8×10^{-6}	1×10^{-12}	3×10^{-8}
	Pu 241	S	9×10^{-11}	7×10^{-3}	3×10^{-12}	2×10^{-6}
		I	4×10^{-9}	4×10^{-3}	1×10^{-10}	1×10^{-6}
	Pu 242	S	2×10^{-13}	1×10^{-6}	6×10^{-14}	5×10^{-9}
		I	4×10^{-11}	9×10^{-6}	1×10^{-12}	3×10^{-8}
	Pu 243	S	2×10^{-6}	1×10^{-3}	6×10^{-8}	3×10^{-4}
		I	2×10^{-6}	1×10^{-3}	8×10^{-8}	3×10^{-4}
	Pu 244	S	2×10^{-13}	1×10^{-6}	6×10^{-14}	4×10^{-9}
		I	3×10^{-11}	3×10^{-6}	1×10^{-12}	1×10^{-8}
Polonium (84)	Po 210	S	5×10^{-10}	2×10^{-6}	2×10^{-11}	7×10^{-7}
		I	2×10^{-10}	8×10^{-6}	7×10^{-12}	3×10^{-8}
Potassium (19)	K42	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Praseodymium (59)	Pr 142	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Pr 143	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
Promethium (61)	Pm 147	S	6×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
		I	1×10^{-7}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Pm 149	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Protoactinium (91)	Pa 230	S	2×10^{-9}	7×10^{-3}	6×10^{-11}	2×10^{-4}
		I	8×10^{-10}	7×10^{-3}	3×10^{-11}	2×10^{-4}
	Pa 231	S	1×10^{-12}	3×10^{-6}	4×10^{-14}	9×10^{-7}
		I	1×10^{-10}	8×10^{-6}	4×10^{-12}	2×10^{-5}
	Pa 233	S	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
		I	2×10^{-7}	3×10^{-3}	6×10^{-9}	1×10^{-4}
Radium (88)	Ra 223	S	2×10^{-9}	2×10^{-5}	6×10^{-11}	7×10^{-7}
		I	2×10^{-10}	1×10^{-4}	8×10^{-12}	4×10^{-6}
	Ra 224	S	5×10^{-9}	7×10^{-5}	2×10^{-10}	2×10^{-6}
		I	7×10^{-10}	2×10^{-4}	2×10^{-11}	5×10^{-6}
	Ra 226	S	3×10^{-11}	4×10^{-7}	3×10^{-12}	3×10^{-8}
		I	5×10^{-11}	9×10^{-4}	2×10^{-12}	3×10^{-8}
	Ra 228	S	7×10^{-11}	8×10^{-7}	2×10^{-12}	3×10^{-8}
		I	4×10^{-11}	7×10^{-4}	1×10^{-12}	3×10^{-8}
Radon (86)	Rn 220	S	3×10^{-7}	.....	1×10^{-8}	
	Rn 222[2]		3×10^{-9}	.....	3×10^{-9}	

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)
Krypton (36)	Kr 85m	Sub	6×10^{-6}	.....	1×10^{-7}	
	Kr 85	Sub	1×10^{-5}	.....	3×10^{-7}	
	Kr 87	Sub	1×10^{-6}	.....	2×10^{-8}	
	Kr 88	Sub	1×10^{-6}	.....	2×10^{-8}	
Lanthanum (57)	La 140	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	1×10^{-7}	7×10^{-4}	4×10^{-9}	2×10^{-5}
Lead (82)	Pb 203	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	Pb 210	S	1×10^{-10}	4×10^{-6}	4×10^{-12}	1×10^{-7}
		I	2×10^{-10}	5×10^{-3}	8×10^{-12}	2×10^{-4}
	Pb 212	S	2×10^{-8}	6×10^{-4}	6×10^{-10}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
Lutetium (71)	Lu 177	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Manganese (25)	Mn 52	S	2×10^{-7}	1×10^{-3}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Mn 54	S	4×10^{-7}	4×10^{-3}	1×10^{-8}	1×10^{-4}
		I	4×10^{-8}	3×10^{-3}	1×10^{-9}	1×10^{-4}
	Mn 56	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Mercury (80)	Hg 197m	S	7×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
		I	8×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Hg 197	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
	Hg 203	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
Molybdenum (42)	Mo 99	S	7×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		I	2×10^{-7}	1×10^{-2}	7×10^{-9}	4×10^{-5}
Neodymium (60)	Nd 144	S	8×10^{-11}	2×10^{-2}	3×10^{-12}	7×10^{-5}
		I	3×10^{-10}	2×10^{-2}	1×10^{-11}	8×10^{-5}
	Nd 147	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	6×10^{-5}
	Nd 149	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	1×10^{-6}	8×10^{-3}	5×10^{-8}	3×10^{-4}
Neptunium (93)	Np 237	S	4×10^{-13}	9×10^{-5}	1×10^{-13}	3×10^{-5}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	Np 239	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	7×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
Nickel (28)	Ni 59	S	5×10^{-7}	6×10^{-3}	2×10^{-8}	2×10^{-4}
		I	8×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-3}
	Ni 63	S	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	7×10^{-4}
	Ni 65	S	9×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Niobium (Columbium) (41)	Nb 93m	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-3}	5×10^{-9}	4×10^{-4}
	Nb 95	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	1×10^{-7}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Nb 97	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
Osmium (76)	Os 185	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	7×10^{-5}
	Os 191m	S	2×10^{-5}	7×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	7×10^{-2}	3×10^{-7}	2×10^{-3}
	Os 191	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Os 193	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	3×10^{-7}	2×10^{-3}	9×10^{-9}	5×10^{-5}

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)
Rhenium (75)	Re 183	S	3×10^{-6}	2×10^{-3}	9×10^{-9}	6×10^{-6}
		I	2×10^{-7}	8×10^{-3}	5×10^{-9}	3×10^{-6}
	Re 186	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-6}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-6}
	Re 187	S	9×10^{-6}	7×10^{-3}	3×10^{-7}	3×10^{-3}
		I	5×10^{-7}	4×10^{-3}	2×10^{-8}	2×10^{-3}
	Re 188	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-6}
		I	2×10^{-7}	9×10^{-6}	6×10^{-9}	3×10^{-6}
Rhodium (45)	Rh 103m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
		I	6×10^{-5}	3×10^{-1}	2×10^{-6}	1×10^{-2}
	Rh 105	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Rubidium (37)	Rb 86	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-6}
		I	7×10^{-8}	7×10^{-4}	2×10^{-9}	2×10^{-6}
	Rb 87	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	7×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Ruthenium (44)	Ru 97	S	2×10^{-6}	1×10^{-2}	8×10^{-9}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
	Ru 103	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-6}
		I	8×10^{-8}	2×10^{-3}	3×10^{-9}	8×10^{-6}
	Ru 105	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Ru 106	S	8×10^{-8}	4×10^{-4}	3×10^{-9}	1×10^{-5}
		I	6×10^{-8}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Samarium (62)	Sm 147	S	7×10^{-11}	2×10^{-3}	2×10^{-12}	6×10^{-6}
		I	3×10^{-10}	2×10^{-3}	9×10^{-12}	7×10^{-6}
	Sm 151	S	6×10^{-6}	1×10^{-2}	2×10^{-8}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Sm 153	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	6×10^{-6}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-6}
Scandium (21)	Sc 46	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-6}	1×10^{-2}	8×10^{-10}	4×10^{-4}
	Sc 47	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
	Sc 48	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Selenium 34)	Se 75	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	1×10^{-7}	8×10^{-3}	4×10^{-9}	3×10^{-4}
Silicon (14)	Si 31	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	1×10^{-6}	6×10^{-3}	3×10^{-8}	2×10^{-4}
Silver (47)	Ag 105	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	8×10^{-8}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Ag 110m	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	1×10^{-6}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Ag 111	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Sodium (11)	Na 22	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	9×10^{-9}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Na 24	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Strontium (38)	Sr 85m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
		I	3×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
	Sr 85	S	2×10^{-7}	3×10^{-3}	8×10^{-9}	1×10^{-4}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Sr 89	S	3×10^{-8}	3×10^{-4}	3×10^{-10}	3×10^{-6}
		I	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Sr 90	S	1×10^{-8}	1×10^{-4}	3×10^{-11}	3×10^{-7}
		I	5×10^{-8}	1×10^{-3}	2×10^{-10}	4×10^{-6}
	Sr 91	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	1×10^{-3}	9×10^{-9}	5×10^{-5}
	Sr 92	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Sulfur (16)	S 35	S	3×10^{-7}	2×10^{-3}	9×10^{-9}	6×10^{-5}
		I	3×10^{-7}	8×10^{-3}	9×10^{-9}	3×10^{-4}

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See notes at end of appendix]

Element (atomic number)	Isotope [1]		Table I Col. 1 Air (μCi/ml)	Table I Col. 2 Water (μCi/ml)	Table II Col. 1 Air (μCi/ml)	Table II Col. 2 Water (μCi/ml)
Tantalum (73)	Ta 182	S	4×10^{-6}	1×10^{-3}	1×10^{-9}	4×10^{-6}
		I	2×10^{-6}	1×10^{-3}	7×10^{-10}	4×10^{-6}
Technetium (43)	Tc 96m	S	8×10^{-5}	4×10^{-1}	3×10^{-8}	1×10^{-3}
		I	3×10^{-5}	3×10^{-1}	1×10^{-8}	1×10^{-3}
	Tc 96	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-6}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-6}
	Tc 97m	S	2×10^{-6}	1×10^{-3}	8×10^{-8}	4×10^{-6}
		I	2×10^{-7}	5×10^{-3}	5×10^{-9}	2×10^{-6}
	Tc 97	S	1×10^{-5}	5×10^{-3}	4×10^{-7}	2×10^{-3}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-6}
	Tc 99m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
		I	1×10^{-5}	8×10^{-3}	5×10^{-7}	3×10^{-3}
	Tc 99	S	2×10^{-6}	1×10^{-3}	7×10^{-8}	3×10^{-6}
		I	6×10^{-6}	5×10^{-3}	2×10^{-8}	2×10^{-6}
Tellurium (52)	Te 125m	S	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-6}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-6}
	Te 127m	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-6}
		I	4×10^{-8}	2×10^{-3}	1×10^{-8}	5×10^{-6}
	Te 127	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-6}
	Te 129m	S	6×10^{-6}	1×10^{-3}	3×10^{-8}	3×10^{-6}
		I	3×10^{-6}	6×10^{-4}	1×10^{-8}	2×10^{-6}
	Te 129	S	5×10^{-6}	2×10^{-3}	2×10^{-7}	8×10^{-6}
		I	4×10^{-6}	2×10^{-3}	1×10^{-7}	8×10^{-6}
	Te 131m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-6}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-6}
	Te 132	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-6}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-6}
Terbium (65)	Tb 160	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-6}
		I	3×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-6}
Thallium (81)	Tl 200	S	3×10^{-6}	1×10^{-3}	9×10^{-8}	4×10^{-6}
		I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-6}
	Tl 201	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-6}
	Tl 202	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-6}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	7×10^{-6}
	Tl 204	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-6}
		I	3×10^{-8}	2×10^{-3}	9×10^{-10}	6×10^{-6}
Thorium (90)	Th 227	S	3×10^{-10}	5×10^{-6}	1×10^{-11}	2×10^{-8}
		I	2×10^{-10}	5×10^{-6}	6×10^{-12}	2×10^{-8}
	Th 228	S	9×10^{-12}	2×10^{-6}	3×10^{-13}	7×10^{-9}
		I	6×10^{-12}	4×10^{-6}	2×10^{-13}	10^{-8}
	Th 230	S	2×10^{-12}	5×10^{-8}	8×10^{-14}	2×10^{-6}
		I	10^{-11}	9×10^{-6}	3×10^{-13}	3×10^{-8}
	Th 231	S	1×10^{-6}	7×10^{-3}	5×10^{-8}	2×10^{-6}
		I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-6}
	Th 232	S	3×10^{-11}	5×10^{-6}	1×10^{-12}	2×10^{-6}
		I	3×10^{-11}	1×10^{-3}	1×10^{-12}	4×10^{-6}
	Th natural	S	8×10^{-11}	6×10^{-6}	2×10^{-12}	2×10^{-6}
		I	6×10^{-11}	6×10^{-6}	2×10^{-12}	2×10^{-6}
	Th 234	S	6×10^{-6}	5×10^{-6}	2×10^{-8}	2×10^{-6}
		I	3×10^{-6}	5×10^{-6}	1×10^{-8}	2×10^{-6}
Thulium (69)	Tm 170	S	4×10^{-6}	1×10^{-3}	1×10^{-9}	5×10^{-6}
		I	3×10^{-6}	1×10^{-3}	1×10^{-9}	5×10^{-6}
	Tm 171	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	5×10^{-6}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-6}
Tin (50)	Sn 113	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-6}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	8×10^{-6}
	Sn 125	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-6}
		I	8×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-6}
Tungsten (Wolfram) (74)	W 181	S	2×10^{-6}	1×10^{-3}	8×10^{-8}	4×10^{-6}
		I	1×10^{-7}	1×10^{-3}	4×10^{-9}	3×10^{-6}
	W 185	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-6}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-6}
	W 187	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-6}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-6}

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See notes at end of appendix]

Element (atomic number)	Isotope		Table I Col. 1 Air (μCi/ml)	Table I Col. 2 Water (μCi/ml)	Table II Col. 1 Air (μCi/ml)	Table II Col. 2 Water (μCi/ml)
Uranium (92)	U 230	S	3×10^{-10}	1×10^{-4}	1×10^{-11}	5×10^{-6}
		I	1×10^{-10}	1×10^{-4}	4×10^{-12}	5×10^{-6}
	U 232	S	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
		I	3×10^{-11}	8×10^{-4}	9×10^{-13}	3×10^{-5}
	U 233	S	5×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	U 234	S[4]	6×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	U 235	S[4]	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	U 236	S	6×10^{-10}	1×10^{-3}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	1×10^{-3}	4×10^{-12}	3×10^{-5}
	U 238	S[4]	7×10^{-11}	1×10^{-3}	3×10^{-12}	4×10^{-5}
		I	1×10^{-10}	1×10^{-3}	5×10^{-12}	4×10^{-5}
	U 240	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
	U-natural	S[4]	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
		I	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
Vanadium (23)	V 48	S	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
		I	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
Xenon (54)	Xe 131m	Sub	2×10^{-6}	.....	4×10^{-7}	.....
	Xe 133	Sub	1×10^{-6}	.....	3×10^{-7}	.....
	Xe 133m	Sub	1×10^{-6}	.....	3×10^{-7}	.....
	Xe 135	Sub	4×10^{-6}	.....	1×10^{-7}	.....
Ytterbium (70)	Yb 175	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Yttrium (39)	Y 90	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	Y 91m	S	2×10^{-6}	1×10^{-1}	8×10^{-7}	3×10^{-3}
		I	2×10^{-6}	1×10^{-1}	6×10^{-7}	3×10^{-3}
	Y 91	S	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
		I	3×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Y 92	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Y 93	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Zinc (30)	Zn 65	S	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
	Zn 69m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Zn 69	S	7×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	9×10^{-6}	5×10^{-2}	3×10^{-7}	2×10^{-3}
Zirconium (40)	Zr 93	S	1×10^{-7}	2×10^{-3}	4×10^{-9}	8×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
	Zr 95	S	1×10^{-7}	2×10^{-3}	4×10^{-9}	6×10^{-5}
		I	9×10^{-8}	2×10^{-3}	1×10^{-9}	6×10^{-5}
	Zr 97	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	9×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than 2 hours.		Sub	1×10^{-6}	.....	3×10^{-8}	.....
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours.			3×10^{-9}	9×10^{-6}	1×10^{-10}	3×10^{-4}
Any single radionuclide not listed above, which decays by alpha emission or spontaneous fission.			6×10^{-13}	4×10^{-7}	2×10^{-14}	3×10^{-6}

[1]Soluble (S); Insoluble (I).

[2]"Sub" means that values given are for submersion in a semispherical infinite cloud of airborne material.

[3]These radon concentrations are appropriate for protection from radon-222 combined with its short-lived daughters. Alternatively, the value in Table I may be replaced by one-third (⅓) "working level." (A "working level" is defined as any combination of short-lived radon-222 daughters, polonium-218, lead-214, bismuth-214 and polonium-214, in one liter of air, without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3×10^{5} MeV of alpha particle energy.) The Table II value

may be replaced by one-thirtieth (1/30) of a "working level." The limit on radon-222 concentrations in restricted areas may be based on an annual average.

[4]For soluble mixtures of U-238, U-234 and U-235 in air chemical toxicity may be the limiting factor. If the percent by weight-enrichment) of U-235 is less than 5, the concentration value for a 40-hour workweek, Table I, is 0.2 milligrams uranium per cubic meter of air average. For any enrichment, the product of the average concentration and time of exposure during a 40-hour workweek shall not exceed 6×10^{-3} SA μCi-hr/ml, where SA is the specific activity of the uranium inhaled. The concentration value for Table II is 0.007 milligrams uranium per cubic meter of air. The specific activity for natural uranium is 6.77×10^{-7} curies per gram U. The specific activity for other mixtures of U-238, U-235 and U-234, if not known, shall be:

$SA=3.6\times10^{-7}$ curies/gram U U-depleted

$SA=(0.4+0.38\ E+0.0034\ E^2)\ 10^{-6}$ $E \geq 0.72$

where E is the percentage by weight of U-235, expressed as percent.

NOTE: In any case where there is a mixture in air or water of more than one radionuclide, the limiting values for purposes of this Appendix should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide in the mixture, the ratio between the quantity present in the mixture and the limit otherwise established in Appendix B for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture may not exceed "1" (i.e., "unity")

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C, and if the applicable MPC's, are MPC_A, and MPC_B, and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

$(C_A/MPC_A)+(C_B/MPC_B)+(C_C/MPC_C) \leq 1$

2. If either the identity or the concentration of any radionuclide in the mixture is not known, the limiting values for purposes of Appendix B shall be:

a. For purposes of Table I, Col. 1—6×10^{-13}

b. For purposes of Table I, Col. 2—4×10^{-7}

c. For purposes of Table II, Col. 1—2×10^{-14}

d. For purposes of Table II, Col. 2—3×10^{-9}

3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in paragraph 2 above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of the radionuclides in the mixture is not known the concentration limit for the mixture is the limit specified in Appendix "B" for the radionuclide in the mixture having the lowest concentration limit; or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in Appendix "B" are not present in the mixture, the concentration limit for the mixture is the lowest concentration limit specified in Appendix "B" for any radionuclide which is not known to be absent from the mixture; or

c. Element (atomic number) and isotope	Table I		Table II	
	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)	Col. 1 Air (μCi/ml)	Col. 2 Water (μCi/ml)
If it is known that Sr 90, I 125, I 126, I 129, I 131 (I 133, table II only), Pb 210, Po 210, At 211, Ra 223, Ra 224, Ra 226, Ac 227, Ra 228, Th 230, Pa 231, Th 232, Th-nat, Cm 248, Cf 254, and Fm 256 are not present.	.....	9×10^{-8}	.....	3×10^{-6}
If it is known that Sr 90, I 125, I 126, I 129 (I 131, I 133, table II only), Pb 210, Po 210, Ra 223, Ra 226, Ra 228, Pa 231, Th-nat, Cm 248, Cf 254, and Fm 256 are not present.	.....	6×10^{-8}	.....	2×10^{-6}
If it is known that Sr 90, I 129 (I 125, I 126, I 131, table II only), Pb 210, Ra 226, Ra 228, Cm 248, and Cf 254 are not present.	.....	2×10^{-8}	.....	6×10^{-7}
If it is known that (I 129, table II only), Ra 226, and Ra 228 are not present	.....	3×10^{-9}	.....	1×10^{-7}
If it is known that alpha-emitters and Sr 90, I 129, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present.	3×10^{-9}	.....	1×10^{-10}	.....
If it is known that alpha-emitters and Pb 210, Ac 227, Ra 226, and Pu 241 are not present.	3×10^{-10}	.....	1×10^{-11}	.....
If it is known that alpha-emitters and Ac 227 are not present	3×10^{-11}	.....	1×10^{-12}	.....
If it is known that Ac 227, Th 230, Pa 231, Pu 236, Pu 239, Pu 240, Pu 242, Pu 244, Cm 248, Cf 249 and Cf 251 are not present.	3×10^{-12}	.....	1×10^{-13}	.....

4. If a mixture of radionuclides consists of uranium and its daughters in ore dust prior to chemical separation of the uranium from the ore, the values specified below may be used for uranium and its daughters through radium-226, instead of those from paragraphs 1, 2, or 3 above.

a. For purposes of Table I, Col. 1—1×10^{-10} μCi/ml gross alpha activity; or 5×10^{-11} μCi/ml natural uranium or 75 micrograms per cubic meter of air natural uranium.

b. For purposes of Table II, Col. 1—3×10^{-12} μCi/ml gross alpha activity; 2×10^{-13} μCi/ml natural uranium; or 3 micrograms per cubic meter of air natural uranium.

5. For purposes of this note, a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture (C_A) to the concentration limit for that radionuclide specified in Table II of Appendix "B"

(MPC_A) does not exceed 1/10, (i.e. $C_A/MPC_A \leq 1/10$) and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed 1 i.e.

$(C_A/MPC_A + C_B/MPC_B \ldots\ldots + \leq 1)$.

[25 FR 10914, Nov. 17, 1960, as amended at 25 FR 13953, Dec. 30, 1960; 26 FR 11046, Nov. 25, 1961; 29 FR 14435, Oct. 21, 1964; 30 FR 15801, Dec. 22, 1965; 31 FR 86, Jan. 5, 1966; 37 FR 23319, Nov. 2, 1972; 38 FR 29314, Oct. 24, 1973; 39 FR 23990, June 28, 1974; 39 FR 25463, July 11, 1974; 39 FR 27121, July 25, 1974; 40 FR 50705, Oct. 31, 1975]

ENVIRONMENTAL PROTECTION AGENCY

TITLE 40 CODE OF FEDERAL
REGULATIONS PART 141

INTERIM PRIMARY DRINKING WATER STANDARDS

the Administrator's affirmative determination pursuant to section 312(f)(3) of the Act. Upon receipt of an application under section 312(f)(3) of the Act, the Administrator will determine within 90 days whether adequate facilities for the safe and sanitary removal and treatment of sewage from all vessels using such waters are reasonably available. Applications made by States pursuant to section 312(f)(3) of the Act shall include: (1) A certification that the protection and enhancement of the waters described in the petition require greater environmental protection than the applicable Federal standard; (2) a map showing the location of commercial and recreational pump-out facilities; (3) a description of the location of pump-out facilities within waters designated for no discharge; (4) the general schedule of operating hours of the pump-out facilities; (5) the draught requirements on vessels that may be excluded because of insufficient water depth adjacent to the facility; (6) information indicating that treatment of wastes from such pump-out facilities is in conformance with Federal law; and (7) information on vessel population and vessel usage of the subject waters.

(b) A State may make a written application to the Administrator, Environmental Protection Agency, under section 312(f)(4) of the Act, for the issuance of a regulation completely prohibiting discharge from a vessel of any sewage, whether treated or not, into particular waters of the United States or specified portions thereof, which waters are located within the boundaries of such State. Such application shall specify with particularly the waters, or portions thereof, for which a complete prohibition is desired. The application shall include identification of water recreational areas, drinking water intakes, aquatic sanctuaries, identifiable fish-spawning and nursery areas, and areas of intensive boating activities. If, on the basis of the State's application and any other information available to him, the Administrator is unable to make a finding that the waters listed in the application require a complete prohibition of any discharge in the waters or portions thereof covered by the application, he shall state the reasons why he cannot make such a finding, and shall deny the application. If the Administrator makes a finding that the waters listed in the application require a complete prohibition of any discharge in all or any part of the waters or portions thereof covered by the State's application, he shall publish notice of such findings together with a notice of proposed rule making, and then shall proceed in accordance with 5 U.S.C. 553. If the Administrator's finding is that applicable water quality standards require a complete prohibition covering a more restricted or more expanded area than that applied for by the State, he shall state the reasons why his finding differs in scope from that requested in the State's application.

(1) For the following waters the discharge from a vessel of any sewage (whether treated or not) is completely prohibited:

Boundary Waters Canoe Area, formerly designated as the Superior, Little Indian Sioux, and Caribou Roadless Areas, in the Superior National Forest, Minnesota, as described in 16 U.S.C. 577-577d1.

[41 FR 4453, Jan. 29, 1976, as amended at 42 FR 43837, Aug. 31, 1977]

§ 140.5 Analytical procedures.

In determining the composition and quality of effluent discharge from marine sanitation devices, the procedures contained in 40 CFR Part 136, "Guidelines Establishing Test Procedures for the Analysis of Pollutants," or subsequent revisions or amendments thereto, shall be employed.

PART 141—NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

Subpart A—General

Sec.

Subpart B—Maximum Contaminant Levels

AUTHORITY: Secs. 1412, 1414, 1445, and 1450 of the Public Health Service Act, 88 Stat. 1660 (42 U.S.C. 300g-1, 300g-3, 300j-4, and 300j-9).

SOURCE: 40 FR 59570, Dec. 24, 1975, unless otherwise noted.

EFFECTIVE DATE NOTE: For community water systems serving 75,000 or more persons, monitoring must begin 1 year following promulgation and the effective date of the MCL is 2 years following promulgation. For community water systems serving 10,000 to 75,000 persons, monitoring must begin within 3 years from the date of promulgation and the effective date of the MCL is 4 years from the date of promulgation. Effective immediately, systems that plan to make significant modifications to their treatment processes for the purpose of complying with the TTHM MCL are required to seek and obtain State approval of their treatment modification plans. This note affects §§ 141.2, 141.6, 141.12, 141.24 and 141.30. For additional information see 44 FR 68641, Nov. 29, 1979.

Subpart A—General

§ 141.1 Applicability.

This part establishes primary drinking water regulations pursuant to section 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act (Pub. L. 93-523); and related regulations applicable to public water systems.

§ 141.2 Definitions.

As used in this part, the term:

(a) "Act" means the Public Health Service Act, as amended by the Safe Drinking Water Act, Pub. L. 93-523.

(b) "Contaminant" means any physical, chemical, biological, or radiological substance or matter in water.

(c) "Maximum contaminant level" means the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

(d) "Person" means an individual, corporation, company, association, partnership, State, municipality, or Federal agency.

(e) "Public water system" means a system for the provision to the public of piped water for human consump-

tion, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. A public water system is either a "community water system" or a "noncommunity water system."

(i) "Community water system" means a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

(ii) "Non-community water system" means a public water system that is not a community water system.

(f) "Sanitary survey" means an onsite review of the water source, facilities, equipment, operation and maintenance of a public water system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water.

(g) "Standard sample" means the aliquot of finished drinking water that is examined for the presence of coliform bacteria.

(h) "State" means the agency of the State government which has jurisdiction over public water systems. During any period when a State does not have primary enforcement responsibility pursuant to Section 1413 of the Act, the term "State" means the Regional Administrator, U.S. Environmental Protection Agency.

(i) "Supplier of water" means any person who owns or operates a public water system.

(j) "Dose equivalent" means the product of the absorbed dose from ionizing radiation and such factors as account for differences in biological effectiveness due to the type of radiation and its distribution in the body as specified by the International Commission on Radiological Units and Measurements (ICRU).

(k) "Rem" means the unit of dose equivalent from ionizing radiation to the total body or any internal organ or organ system. A "millirem (mrem)" is 1/1000 of a rem.

(l) "Picocurie (pCi)" means the quantity of radioactive material producing 2.22 nuclear transformations per minute.

(m) "Gross alpha particle activity" means the total radioactivity due to alpha particle emission as inferred from measurements on a dry sample.

(n) "Man-made beta particle and photon emitters" means all radionuclides emitting beta particles and/or photons listed in Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure, NBS Handbook 69, except the daughter products of thorium-232, uranium-235 and uranium-238.

(o) "Gross boat particle activity" means the total radioactivity due to beta particle emission as inferred from measurements on a dry sample.

(p) "Halogen" means one of the chemical elements chlorine, bromine or iodine.

(q) "Trihalomethane" (THM) means one of the family of organic compounds, named as derivatives of methane, wherein three of the four hydrogen atoms in methane are each substituted by a halogen atom in the molecular structure.

(r) "Total trihalomethanes" (TTHM) means the sum of the concentration in milligrams per liter of the trihalomethane compounds (trichloromethane [chloroform], dibromochloromethane, bromodichloromethane and tribromomethane [bromoform]), rounded to two significant figures.

(s) "Maximum Total Trihalomethane Potential (MTP)" means the maximum concentration of total trihalomethanes produced in a given water containing a disinfectant residual after 7 days at a temperature of 25° C or above.

(t) "Disinfectant" means any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution proc-

[illegible] is intended to kill or inactivate pathogenic microorganisms.

[illegible] Dec. 24, 1975, as amended at [illegible] July 9, 1976; 44 FR 68641, Nov. [illegible] 1979.

§ 141.3 Coverage.

This part shall apply to each public water system, unless the public water system meets all of the following conditions:

(a) Consists only of distribution and storage facilities (and does not have any collection and treatment facilities);

(b) Obtains all of its water from, but is not owned or operated by, a public water system to which such regulations apply;

(c) Does not sell water to any person; and

(d) Is not a carrier which conveys passengers in interstate commerce.

§ 141.4 Variances and exemptions.

Variances or exemptions from certain provisions of these regulations may be granted pursuant to Sections 1415 and 1416 of the Act by the entity with primary enforcement responsibility. Provisions under Part 142, *National Interim Primary Drinking Water Regulations Implementation*—Subpart E Variances) and Subpart F (Exemptions)—apply where EPA has primary enforcement responsibility.

§ 141.5 Siting requirements.

Before a person may enter into a financial commitment for or initiate construction of a new public water system or increase the capacity of an existing public water system, he shall notify the State and, to the extent practicable, avoid locating part or all of the new or expanded facility at a site which:

(a) Is subject to a significant risk from earthquakes, floods, fires or other disasters which could cause a breakdown of the public water system or a portion thereof; or

(b) Except for intake structures, is within the floodplain of a 100-year flood or is lower than any recorded high tide where appropriate records exist. The U.S. Environmental Protection Agency will not seek to override land use decisions affecting public water systems siting which are made at the State or local government levels.

§ 141.6 Effective dates.

(a) Except as provided in paragraph (b) of this section, the regulations set forth in this part shall take effect on June 24, 1977.

(b) The regulations for total trihalomethanes set forth in § 141.12(c) shall take effect 2 years after the date of promulgation of these regulations for community water systems serving 75,000 or more individuals, and 4 years after the date of promulgation for communities serving 10,000 to 74,999 individuals.

[44 FR 68641, Nov. 29, 1979]

Subpart B—Maximum Contaminant levels

§ 141.11 Maximum contaminant levels for inorganic chemicals.

(a) The maximum contaminant level for nitrate is applicable to both community water systems and non-community water systems. The levels for the other inorganic chemicals apply only to community water systems. Compliance with maximum contaminant levels for inorganic chemicals is calculated pursuant to § 141.23.

(b) The following are the maximum contaminant levels for inorganic chemicals other than fluoride:

Contaminant	Level, milligrams per liter
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05

(c) When the annual average of the maximum daily air temperatures for the location in which the community water system is situated is the following, the maximum contaminant levels for fluoride are:

Temperature Degrees Fahrenheit	Degrees Celsius	Level, milligrams per liter
53.7 and below	12.0 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

§ 141.12 Maximum contaminant levels for organic chemicals.

The following are the maximum contaminant levels for organic chemicals. The maximum contaminant levels for organic chemicals in paragraphs (a) and (b) of this section apply to all community water systems. Compliance with the maximum contaminant levels in paragraphs (a) and (b) is calculated pursuant to § 141.24. The maximum comtaminant level for total trihalomethanes in paragraph (c) of this section applies only to community water systems which serve a population of 10,000 or more individuals and which add a disinfectant (oxidant) to the water in any part of the drinking water treatment process. Compliance with the maximum contaminant level for total trihalomethanes is calculated pursuant to § 141.30.

	Level, milligrams per liter
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-hexachloro-6, 7-epoxy-1,4, 4a,5,6,7,8,81-octahydro-1,4-endo, endo-5,8-dimethano naphthalene).	0.0002
Lindane (1,2,3,4,5,6-hexachlorocyclo- hexane, gamma isomer).	0.004
Methoxychlor (1,1,1-Trichloro-2, 2-bis [p-methoxyphenyl] ethane).	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67-69 percent chlorine).	0.005
(b) Chlorophenoxys:	
2,4-D, (2,4-Dichlorophenoxyacetic acid)	0.1
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid).	0.01
(c) Total trihalomethanes (the sum of the concentrations of bromodichloromethane, dibromochloromethane, tribromomethane (bromoform) and trichloromethane (chloroform)) 0.10 mg/l.	

[40 FR 59570, Dec. 24, 1975, as amended at 44 FR 68641, Nov. 29, 1979]

§ 141.13 Maximum contaminant levels for turbidity.

The maximum contaminant levels for turbidity are applicable to both community water systems and noncommunity water systems using surface water sources in whole or in part. The maximum contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system, are:

(a) One turbidity unit (TU), as determined by a monthly average pursuant to § 141.22, except that five or fewer turbidity units may be allowed if the supplier of water can demonstrate to the State that the higher turbidity does not do any of the following:

(1) Interfere with disinfection;

(2) Prevent maintenance of an effective disinfectant agent throughout the distribution system; or

(3) Interfere with microbiological determinations.

(b) Five turbidity units based on an average for two consecutive days pursuant to § 141.22.

§ 141.14 Maximum microbiological contaminant levels.

The maximum contaminant levels for coliform bacteria, applicable to community water systems and noncommunity water systems, are as follows:

(a) When the membrane filter technique pursuant to § 141.21(a) is used, the number of coliform bacteria shall not exceed any of the following:

(1) One per 100 milliliters as the arithmetic mean of all samples examined per month pursuant to § 141.21 (b) or (c);

(2) Four per 100 milliliters in more than one sample when less than 20 are examined per month; or

(3) Four per 100 milliliters in more than five percent of the samples when 20 or more are examined per month.

(b) (1) When the fermentation tube method and 10 milliliter standard portions pursuant to § 141.21(a) are used, coliform bacteria shall not be present in any of the following:

(i) More than 10 percent of the portions in any month pursuant to § 141.21 (b) or (c);

(ii) Three or more portions in more than one sample when less than 20 samples are examined per month; or

(iii) Three or more portions in more than five percent of the samples when 20 or more samples are examined per month.

(2) When the fermentation tube method and 100 milliliter standard portions pursuant to § 141.21(a) are used, coliform bacteria shall not be present in any of the following:

(i) More than 60 percent of the portions in any month pursuant to § 141.21 (b) or (c);

(ii) Five portions in more than one sample when less than five samples are examined per month; or

(iii) Five portions in more than 20 percent of the samples when five or more samples are examined per month.

(c) For community or non-community systems that are required to sample at a rate of less than 4 per month, compliance with paragraph (a), (b)(1), or (b)(2) of this section shall be based upon sampling during a 3 month period, except that, at the discretion of the State, compliance may be based upon sampling during a one-month period.

§ 141.15 Maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity in community water systems.

The following are the maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity:

(a) Combined radium-226 and radium-228—5 pCi/1.

(b) Gross alpha particle activity (including radium-226 but excluding radon and uranium)—15 pCi/1.

[41 FR 28404, July 9, 1976]

§ 141.16 Maximum contaminant levels for beta particle and photon radioactivity from man-made radionuclides in community water systems.

(a) The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

(b) Except for the radionuclides listed in Table A, the concentration of man-made radionuclides causing 4 mrem total body or organ dose equivalents shall be calculated on the basis of a 2 liter per day drinking water intake using the 168 hour data listed in *"Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure,"* NBS Handbook 69 as amended August 1963, U.S. Department of Commerce. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year.

TABLE A.—*Average annual concentrations assumed to produce a total body or organ dose of 4 mrem/yr*

Radionuclide	Critical organ	pCi per liter
Tritium	Total body	20,000
Strontium-90	Bone marrow	8

[41 FR 28404, July 9, 1976]

Subpart C—Monitoring and Analytical Requirements

§ 141.21 Microbiological contaminant sampling and analytical requirements.

(a) Suppliers of water for community water systems and non-community water systems shall analyze for coliform bacteria for the purpose of determining compliance with § 141.14. Analyses shall be conducted in accordance with the analytical recommendations set forth in "Standard Methods for the Examination of Water and Wastewater," American Public Health Association, 13th Edition, pp. 662-688, except that a standard sample size shall be employed. The standard sample used in the membrane filter procedure shall be 100 milliliters. The standard sample used in the 5 tube most probable number (MPN) procedure (fermentation tube method) shall be 5 times the standard portion. The standard portion is either 10 milliliters

APPENDIX VI

EVALUATION OF RADIATION EXPOSURES AT THE FORMER KELLEX RESEARCH FACILITY, JERSEY CITY, NEW JERSEY

EVALUATION OF RADIATION EXPOSURES AT THE FORMER KELLEX RESEARCH FACILITY, JERSEY CITY, NEW JERSEY

The U.S. Department of Energy (DOE) has determined that the former Kellex Research Facility in Jersey City, New Jersey, is presently contaminated with radioactive residues resulting from previous uses of this property. The Kellex Corporation was formed by the M. W. Kellogg Company in 1943 for the purpose of designing and constructing the first gaseous diffusion plant for uranium enrichment. Research and development work on the gaseous diffusion process was carried out for the Manhattan Engineer District (MED) at the Jersey City laboratories. Subsequent subcontracts with MED and the Atomic Energy Commission (AEC) also included research and development work toward the purex method of reprocessing nuclear reactor fuel elements. Available information indicates that work involving radioactive materials was conducted in Building 11 and in an unnumbered structure along the southwest boundary of the site. Contractual work was terminated in July, 1952.

A radiological survey conducted in June, 1953, indicated that Building 11 was free of transferable radioactive contamination and external gamma radiation exposures were less than guidelines then in use. Subsequent to that survey, the property was sold to Pierpont Associates, Incorporated. Many of the structures, including all structures suspected of housing radioactive materials, were demolished as portions of the site were developed for other uses.

In March, 1977, a radiological survey was conducted on the concrete pad on which Building 11 once stood. Three of the original Kellex buildings were still existing at the time of that survey. Two of those buildings were occupied; one was used as a machine shop, the other served as a garage. All three of these structures have now been demolished. After the 1977 survey, a portion of the original 43-acre tract was sold for commercial development. That part of the site is now occupied by a shopping center.

Contamination at the former Kellex site is due to small, localized deposits of natural uranium, natural thorium, and radium-226. This contamination will yield slight radiation exposures to persons on the site. These slight radiation exposures result primarily from beta and gamma radiations emitted by the radionuclides in the soil. Any additional radiation exposures received by way of ingestion (e.g., eating or drinking on the site) or inhalation of radioactive materials are relatively small compared with external radiation exposures. A summary of radiation exposures is provided in Table VI-1 along with appropriate guidelines and background values.

The naturally occurring radionuclides present at the former Kellex site are also present in minute quantities throughout our environment. Concentrations of these radionuclides in normal soils, air, water, food, etc., are referred to as background concentrations. Radiation exposures resulting from this environment radioactivity are referred to as background exposures. These background exposures are not caused by any human activity and, to a large extent, can be controlled only through man's moving to areas with lower background exposures. Each and every human receives some background exposure daily.

The use of radioactive materials for scientific, industrial, or medical purposes may cause radiation exposures above the background level to be received by workers in the industry and, to a lesser extent, by members of the general public. Scientifically based guidelines have been developed to place an upper limit on these additional exposures. Limits established for exposures to the general public are much lower than the limits established for workers in the nuclear industry.

Uranium-238 is believed to have been created when the earth was formed. It is still present today because it takes a very long time to decay. The half-life is a measure of the time required for radioactive decay; for uranium-238 it is 4.5 billion years. Thus, if 4.5 billion years ago you had a curie* of uranium-238, today you would

*The curie is a unit used to measure the amount of radioactivity in a substance; one curie represents 37 billion radioactive disintegrations per second.

Table VI-1. Summary of exposure data at the former Kellex site in Jersey City, New Jersey

Exposure source	Background levels	Guideline value for general public	Guideline value for radiation workers	Average levels at the former Kellex site
Gamma radiation from daughters of uranium, radium, and thorium	Background averages 6 microroentgens[a] per hour in New Jersey area	250 microroentgens per hour above natural background for 40 hours per week and 50 weeks per year for an individual in the general public. This is equivalent to 5 roentgens per year	2,500 microroentgens per hour for 40 hours per week and 50 weeks per year. This is equivalent to 5 roentgens per year	Values ranged from approximately 5 to 11 microroentgens per hour at one meter, and averaged about 7 microroentgens per hour
Radon in air	Less than one picocurie[b] per liter of air	Continuous exposure to 3 picocuries per liter of air	Exposure for 40 hours per week and 50 weeks per year to 30 picocuries per liter of air	Estimated concentration is less than one picocurie per liter of air
Radon daughters in air	Less than 0.01 working level[c]	0.01 working level for residences and school rooms, and 0.03 working level for other structures	0.33 working level for uranium miners exposed for 40 hours per week and 50 weeks per year	Estimated average concentration is less than 0.001 working level

[a] The roentgen is a unit of exposure to penetrating X or gamma radiation. A microroentgen is one-millionth of a roentgen.

[b] The picocurie is a unit which was defined for expressing the amount of radioactivity present in a substance.

[c] The working level is a unit which was defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

have one-half curie; 4.5 billion years hence, this would only be one-fourth curie. As the uranium-238 decays, it changes into another substance, thorium-234. Thorium-234 is called the "daughter" of uranium-238. In turn, thorium-234 is the "parent" of protactinium-234. Radioactive decay started by uranium-238 continues as shown in Table VI-2 until stable lead is formed. The "decay product" listed in Table VI-2 is the radiation produced as the parent decays.

Direct Beta and Gamma-Ray Exposures

Nuclear Regulatory Commission (NRC) guidelines state that the combined dose from weakly penetrating beta particles and from gamma rays, measured at a distance of 1 centimeter from any surface, should not exceed 0.2 millirad* per hour when averaged over an area of 1 square meter. The combined dose rate should not exceed 1.0 millirad per hour in small area of 100 square centimeters. No recorded measurement on this site exceeded these guidelines. The highest isolated beta-gamma dose rate on site was 0.6 millirad per hour. Consequently, any incidental exposure from handling the material associated with this isolated spot would be within NRC guidelines.

As may be seen in Table VI-2, several of the daughters of uranium-238 and of radium-226 emit gamma radiation (gamma rays are penetrating radiation like X rays). Hence, the residues on this site are sources of external gamma radiation exposure. External gamma-ray exposures measured at 1 meter above the ground at the former Kellex site ranged from 4 to 11 microroentgens† per hour, with an average of 7 microroentgens per hour. Exposure to this average level for 2,000 hours per year, a typical work year, would lead to an exposure of 14,000 microroentgens. For comparison, a typical chest X ray (according to Department of Health, Education, and Welfare data) might yield

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*The millirad is a unit for measuring the amount of radiation energy absorbed by human tissue.

†The roentgen is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microroentgen is one-millionth of a roentgen.

Table VI-2. Uranium-238 decay series

Parent	Half-life	Decay products	Daughter
uranium-238	4.5 billion years	alpha	thorium-234
thorium-234	24 days	beta, gamma	protactinium-234
protactinium-234	1.2 minutes	beta, gamma	uranium-234
uranium-234	250 thousand years	alpha	thorium-230
thorium-230	80 thousand years	alpha	radium-226
radium-226	1,600 years	alpha	radon-222
radon-222	3.8 days	alpha	polonium-218
polonium-218[a]	3 minutes	alpha	lead-214
lead-214[a]	27 minutes	beta, gamma	bismuth-214
bismuth-214[a]	20 minutes	beta, gamma	polonium-214
polonium-214[a]	$\frac{2}{10,000}$ second	alpha	lead-210
lead-210	22 years	beta	bismuth-210
bismuth-210	5 days	beta	polonium-210
polonium-210	140 days	alpha	lead-206
lead-206	stable	none	none

[a]Short-lived radon daughters.

an exposure of 27,000 microroentgens. Background radiation levels in the Jersey City area averaged 6 microroentgens per hour.

The National Council on Radiation Protection and Measurement (NCRP) has recommended a maximum annual whole-body exposure rate of 500,000 microroentgens per year to an individual continually exposed in the general public. This value corresponds to 250 microroentgens per hour for 2,000 exposure hours (40 hours per week and 50 weeks per year) or to approximately 60 microroentgens per hour for continuous exposure. The NCRP guideline would not be exceeded at any locations on the Kellex site even for continuous occupancy of the site.

Inhalation of Radionuclides

Radon-222, the daughter of radium-226, is an inert gas which may leave the soil and enter the atmosphere. Furthermore, radon can seep through concrete floors and accumulate in poorly ventilated buildings. At the present, no structures on the site are built over the isolated areas contaminated by radium-226. However, if buildings were to be constructed over these contaminated areas, radon concentrations in the buildings could be slightly elevated above normal levels. It is unlikely that the radon concentration in any structures built over the most contaminated soil could exceed the guideline value of 3 picocuries* per liter for exposure of the general public as set forth in 10 CFR 20.†

As may be seen in Table VI-2, the decay of radon-222 produces a series of short-lived daughters. The unit which has been developed to measure the concentration of daughters is the working level.‡ It is estimated that present radon daughter concentrations in air on the site

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*One picocurie is one million-millionth of a curie, previously defined.

†Title 10, Code of Federal Regulations, Part 20, is a regulatory document published by the Nuclear Regulatory Commission and may be found in the *Federal Register*.

‡The working level is a unit which was defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

are much less than 0.001 working level. These concentrations are well below the guideline value of 0.03 working level suggested in 10 CFR 20. It is also doubtful that this guideline value could be exceeded in structures built over the most contaminated soil. However, careful consideration should be given to the location of any structure built on or near presently contaminated areas of this site.

Studies of uranium and other hard-rock miners have established that inhalation of large quantities of daughters of radon-222 over long periods of time increases an individual's risk of contracting lung cancer. The present federal guide value for uranium mine workers (given by the Environmental Protection Agency), when translated to the units discussed here, would limit mine workers to an exposure of 0.33 working level, assuming exposure for 2,000 hours per year, a typical work year. This level is significantly lower than the exposures received by most of the miners included in the studies.

Other Considerations of Exposure

The concentration of radionuclides in groundwater samples taken at the site were all below the concentration guide for water (CG_w) set forth in 10 CFR 20. While no crops are currently grown on this site, use of the contaminated soil for such purposes could produce additional human exposure through consumption of crops which have incorporated radium-226, natural uranium, natural thorium, or other radionuclides. In addition, actions which involve considerable scraping or tilling of dry soil, particularly in the areas showing high concentrations of radionuclides in surface soil, could lead to human exposures through inhalation of airborne radioactive dust.

Risk and Radiation Exposures

Risks resulting from radiation exposures should be considered within the context of other risks incurred in normal living. For simplicity, risks to health may be classified in four categories:

1. Unacceptable--problems with risk so high as to require immediate action, such as severe diseases where medical treatment is required to save a life.
2. Concerned--problems where people are willing to spend time and money to reduce potential hazards. Examples of this include the maintenance of public highways and signs, signals, fire departments, and rescue squads.
3. Recognized--problems where people may accept some inconvenience to avoid certain activities such as flying in airplanes, swimming alone, etc.
4. No great concern--problems with a low frequency of occurrence. There is an awareness of potential hazard but an accompanying feeling that these problems occur only to other people.

An individual may be exposed to risks over which he can exercise some control (voluntary) and risks over which he feels he has no personal control or choice (involuntary).

Daily, an individual is confronted with decisions about risk which have an associated benefit--for example, driving a car. This can serve as an illustration that a voluntary, concerned risk may be deemed appropriate due to the desirable perceived benefit. As another example, an individual who smokes cigarettes has subjected himself to a risk of lung cancer which is about ten times higher than that for a nonsmoker.

For purposes of radiation protection, all radiation exposures are assumed to be capable of increasing an individual's risk of contracting cancer. A precise numerical value cannot be assigned with any certainty to a given individual's increase in risk attributable to radiation exposure. The reasons for this are numerous; they include the individual's age at onset of exposure, variability in latency period (time between exposure and physical evidence of disease), the individual's personal habits and state of health, previous or concurrent exposure to other cancer-causing agents, and the individual's family medical history. Because of these variables, large uncertainties would exist in any estimates of the number of increased cancer

deaths in the relatively small population exposed at the former Kellex site.

The normal annual death rate* from lung cancer for all population groups in Hudson County (as of 1970) was 31.1 deaths per 100,000 population. At the same time, the annual death rates from lung cancer for all population groups in the United States and the state of New Jersey were 21.1 and 25.7 deaths per 100,000 population, respectively. A one-year exposure to the radon daughter guideline value for uranium miners (0.33 working level for 2,000 hours) might increase the risk of death due to lung cancer by approximately four percent.

The annual death rate from all types of cancer among all population groups in Hudson County (as of 1970) was 191 deaths per 100,000 population. At the same time, the death rates from all types of cancer for all population groups in the United States and in the state of New Jersey were 151 and 175 per 100,000 population, respectively. A one-year exposure to penetrating gamma radiation of 500,000 microroentgen might increase the risk of death due to all types of cancer by about one-tenth of a percent. Exposures in excess of these guideline values would be expected to result in proportionately higher increases in risk. Consequently, any action taken to reduce either the rate or the duration of radiation exposures would also reduce the risk attendant to that exposure.

There are no data at present which give evidence of a relationship between low-level exposure of the skin by beta-gamma radiation and the development of skin cancers. This does not mean that skin cancer cannot be produced by low-level exposures. This does mean that the risk associated with guidelines level exposures of the skin is so small that it cannot be quantified.

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*Mortality statistics were obtained from data in *U. S. Cancer Mortality by County: 1950-1969*, prepared by the National Cancer Institute, 1973, available from the U.S. Government Printing Office.

Remedial Measures

The radiation exposures at the former Kellex site are attributable to the presence of natural uranium, natural thorium, and radium-226 deposits in soil in isolated areas of the site. This contamination leads to exposures due to external beta and gamma radiation. Although these present exposures are less than guideline values, more serious exposures caused by ingestion of crops grown in the contaminated areas could be avoided by removal of the contaminated areas of soil. This removal of contaminated areas could be followed by backfilling with uncontaminated soil. The Department of Energy is now actively evaluating this and other alternative measures under a priority program designed to assure public protection.

SUMMARY

The former Kellex site is contaminated with residues resulting from the previous use of this site as a research facility handling materials containing naturally occurring uranium, thorium, and radium-226. This contamination is leading to slight radiation exposures to persons working on or otherwise occupying the site. These result from beta and gamma radiation. Measurements made at the site indicate that such exposures do not exceed pertinent guidelines. However, the use of the contaminated areas on this site to grow crops could lead to human exposure from consumption of contaminated food. Consequently some remedial measures are in order. The Department of Energy has developed a coordinated plan which addresses the specific problems at this landfill site and other formerly utilized MED/AEC sites. Currently, work is under way to implement the elements of this plan.

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